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ECONOMIC GEOLOGY

OF

RICHMOND, VIRGINIA, AND VICINITY

BY

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ECONOMIC GEOLOGY OF RICHMOND, VIRGINIA, AND VICINITY.

By N. H. DARTON.

INTRODUCTION.

The geologic formations in the vicinity of Richmond contain materials of considerable economic importance, notably a very large amount of high-grade granite and wide areas of valuable brick clays. Both of these are extensively utilized, not only for local consumption but for shipment to other places. The granite industry is in a moderately prosperous condition, but the production was formerly much greater than it is at present. Richmond is most favorably situated for the distribution of its economic products, for it has several railroads and is on tidewater.

There is not much literature on the geology of the Richmond region. In the report of the Geological Survey of Virginia, by Prof. W. B. Rogers, issued in 1836–1840, the general relations of the rocks were described and some additional facts have been published by subsequent observers.[1]

Some features of the economic geology were described by T. L. Watson in 1906 [2] and in a later report on the granites of the southeastern Atlantic States.[3]

GEOGRAPHIC FEATURES.

Eastern Virginia consists of two provinces—the Coastal Plain to the east and the Piedmont province to the west—but the two merge insensibly along a zone which lies near Richmond, Fredericksburg, and Washington. The Piedmont province is a region of hard rocks and rolling topography. It was formerly a plateau, but now is so deeply eroded by drainageways that but little of the plateau surface remains.

[1] Coryell, Martin, Diatomaceous sands of Richmond, Va.: Proc. Am. Inst. Min. Eng., vol. 4, p. 230; The Virginias, vol. 2, 1881, pp. 6–7. Darton, N. H., Mesozoic and Cenozoic of eastern Virginia and Maryland: Bull. Geol. Soc. America, vol. 2, 1891, pp. 431–450. Fontaine, W. M., The Potomac formation in Virginia: Bull. U. S. Geol. Survey, No. 145, 1896. Darton, N. H., Artesian well prospects in the Atlantic Coastal Plain region: Bull. U. S. Geol. Survey, No. 138, 1896.

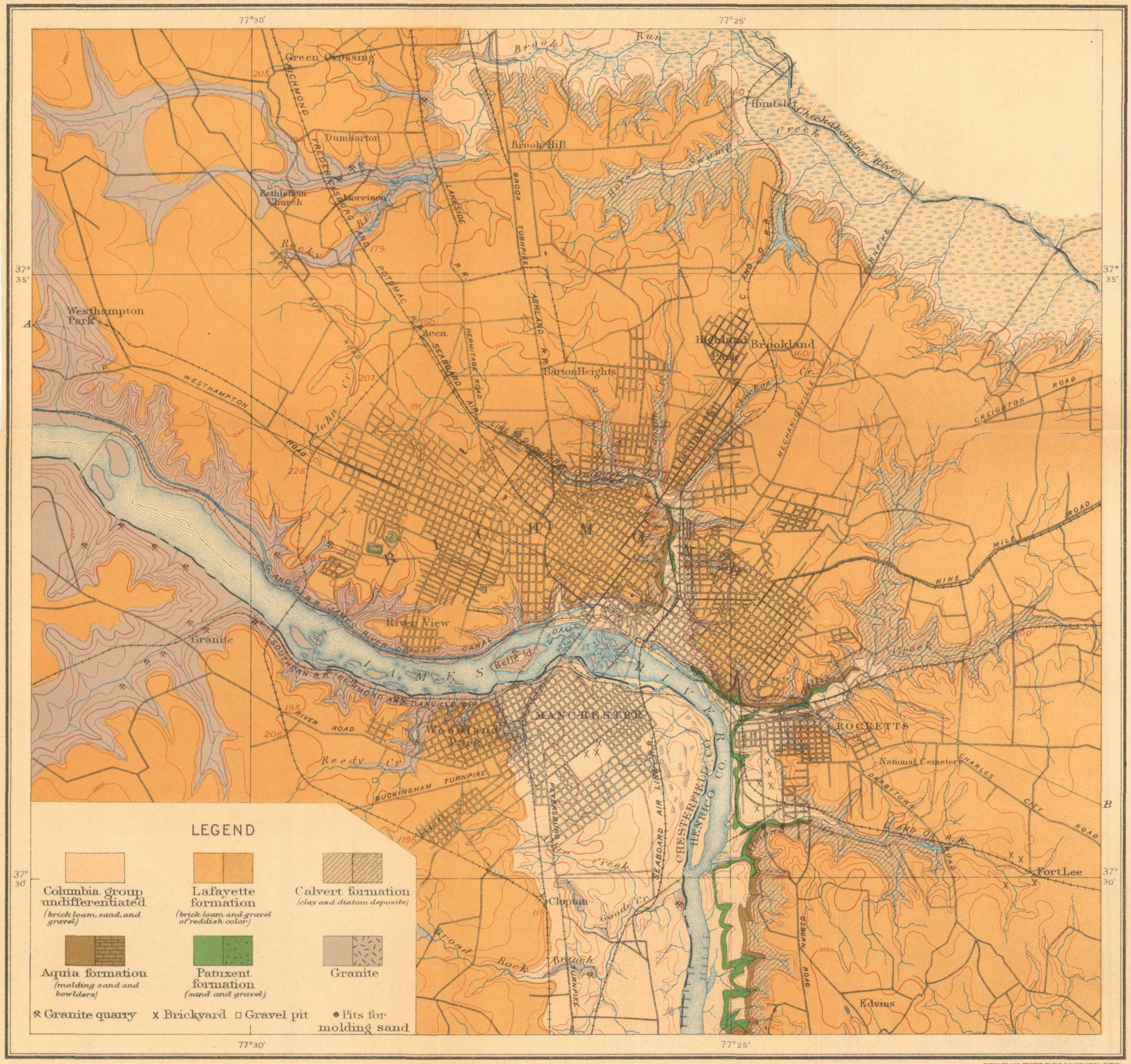
[2] Watson, T. L., Mineral resources of Virginia: The Virginia Jamestown Exposition Commission, Lynchburg, 1907.

[3] Watson, T. L., Granites of the southeastern Atlantic States: Bull. U. S. Geol. Survey No. 426, 1910.

In its eastern part it has an average altitude of about 200 feet above sea level, but it rises gradually toward the west. The streams that cross it flow through narrow valleys in rocky channels. The Coastal Plain is a region of clay, sand, and other soft materials, laid down in a succession of relatively thin sheets on an eastward-sloping floor of granite and other crystalline rocks and dipping gently to the east. It consists mainly of a wide plateau of moderate height trenched by broad, terraced valleys of numerous streams. The larger streams that flow from the Piedmont province are tidal estuaries as far inland as the zone in which the hard rocks rise from under the deposits of the Coastal Plain and become sufficiently high to cause rapids. As the rise of these rocks is in general moderately steep the river valleys narrow in a short distance into rocky gorges which mark the change from the Coastal Plain to the Piedmont province. Richmond is situated at the head of the estuarine portion of James River, and is built partly on the Coastal Plain plateau and partly on the slopes that descend to the river. Manchester is built on a river terrace. The plateau in the Richmond region stands at an average altitude of 200 feet above sea level and has a notably smooth surface. (See Pl. II, *A*.) It stretches far to the west, northeast, and southeast, but is deeply trenched by numerous minor streams, notably Shockoe and Gillis creeks and their branches, and has been widely removed by James and Chickahominy rivers. It reappears south of James River, in the region west of Manchester, where its altitude for some distance is about 200 feet above sea level. The smoothness and the gentle eastward slope of the plateau are notable. West of longitude 77° 30′ it rises at a slightly more rapid rate. The valley of James River is bordered at several heights by terraces, the most extensive of which is the broad one extending southward from Manchester. This terrace rises from the freshet plain of the river and by successive steps attains an altitude of about 100 feet and a width of nearly 2 miles. Apparently it is developed on granite thinly covered with clay, sand, and gravel. A portion of this terrace lies on the north side of the river in Richmond, where it constitutes a well-defined shelf having an altitude of 70 to 90 feet along Carey Street and Canal Street, from Sixth to Eleventh Street. It also borders the valleys of Shockoe and Gillis creeks, where it has an altitude of 30 to 80 feet. Rocketts is built on part of this terrace and there are other parts of it on the east side of the river below the mouth of Almond Creek.

GENERAL STRUCTURAL RELATIONS.

The cross section in Plate I shows the principal structural features of the Richmond region. It passes through the center of Richmond from northwest to southeast. The granite of the Piedmont region descends abruptly under sedimentary strata of the Coastal Plain in



LEGEND

- Columbia group undifferentiated (brick loam, sand, and gravel)
- Lafayette formation (brick loam and gravel of reddish color)
- Calvert formation (clay and diatom deposits)
- Aquia formation (molding sand and bowlders)
- Patuxent formation (sand and gravel)
- Granite

Granite quarry · Brickyard · Gravel pit · Pits for molding sand

Topography by M. Hackett and E.C. Barnard.

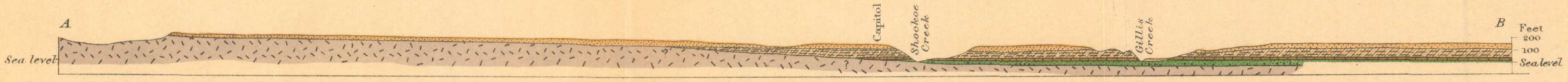
MAP SHOWING ECONOMIC GEOLOGY OF RICHMOND, VA., AND VICINITY

BY N.H. DARTON

Scale 1/62500

1 ½ 0 1 2 Miles

Contour interval 20 feet.
1911



SECTION ALONG LINE A-B

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

the central part of the city and farther southeast it lies several hundred feet below the surface.

The succession of overlying strata is as follows:

Sedimentary rocks in the Richmond region.

System.	Series.	Group.	Formation.	Character.	Thickness.
					Feet.
Quaternary.	Pleistocene.	Columbia.	Undifferentiated.	Loam, sand, and gravel on terraces.	5–35
Tertiary.	Pliocene (?).	.....	Lafayette.	Loam, sand, and gravel of orange tint.	30
	Miocene.	Chesapeake.	Calvert.	Clay with sand and diatom admixture.	0–80
	Eocene.	Pamunkey.	Aquia.	Dark sand; gravel at base.	0–25
Cretaceous.	Lower Cretaceous.	Potomac.	Patuxent (may possibly include some Patapsco at top).	Arkosic sand with gravel, cross-bedded.	0–50

Except the deposits of the Columbia group, which lie in terraces in the valleys, these strata form a succession of widely extended sheets that dip gently to the east. The Lafayette formation constitutes the mantle of the general plateau of the region and extends far to the west, overlapping the edges of the older formations. Its inclination to the east is slight and irregular and it also slopes to some extent into the valleys.

To the east it lies unconformably on the Calvert formation, but without notable discordance of dip or deep channeling.

The Calvert is the lowest formation of the Chesapeake group and, as the other formations of the group are absent, a long interval of time between the Calvert and Lafayette formations is not represented by deposits at Richmond. The Calvert formation overlaps on to the granite in the western part of the city and has a general dip to the east at a very low rate. It lies unconformably on the Aquia formation and thickens slightly to the east and southeast. The Aquia formation is the lower formation of the Pamunkey group, the upper formation of that group, the Nanjemoy, being absent. Therefore there is a considerable hiatus between the Aquia and Calvert formations. The Aquia formation is a thin sheet of dark sand developing into a marl toward the east. It dips gently eastward and also gradually thickens in that direction. It lies unconformably on the Potomac group, there being a hiatus between the two, represented in the other regions by earlier Tertiary and a great thickness of Cretaceous sediments. The Potomac group present in this area probably comprises only the Patuxent formation of the region farther north. The beds lie unconformably on a somewhat irregular surface of the old granite. This surface rises to the west as a shore line

against which the edges of the Patuxent and Aquia formations abut a short distance west of Shockoe Creek valley, as shown in the cross section on Plate I. Both of these formations and most of the Calvert deposits have been removed in the area west of the river, through Manchester, and for some distance south.

DESCRIPTION OF THE ROCKS.

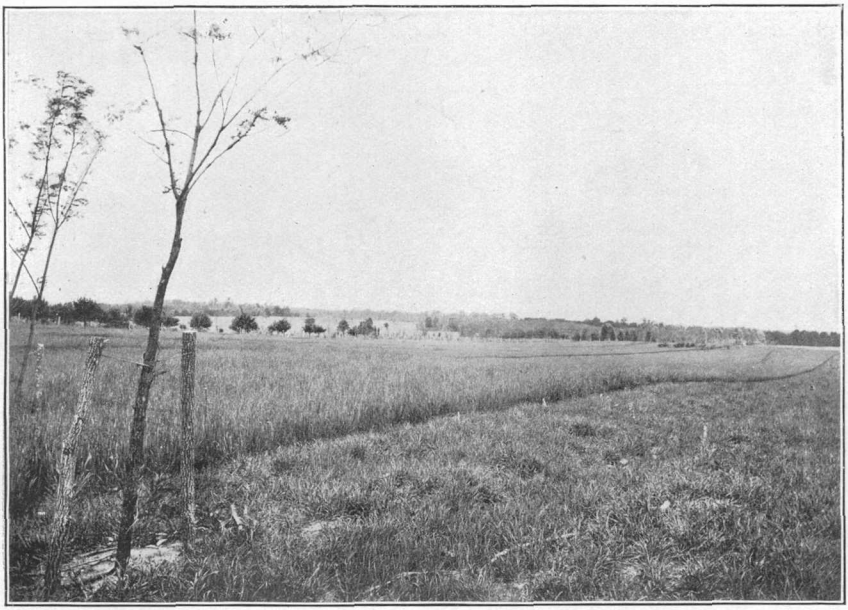
GRANITE.

General features.—The granite which underlies the Richmond region is mostly massive and is of light-gray color. It consists mainly of the three crystalline minerals, quartz, feldspar, and mica, uniformly intermixed but varying somewhat in proportions and texture. In the western part of Richmond and to the west, and in Chesterfield County, the rock is at or near the surface, although it is extensively mantled by the Lafayette formation on the higher land. In the central part of Richmond and farther east the granite sinks at a steep grade and passes beneath the Patuxent formation. In its area of outcrop much of it is decomposed, so much so in some places that the resulting material is scarcely more than a compact sand, mostly of reddish and yellow tints. The granite outcrops extensively in the cliffs along both sides of James River above Richmond and causes the falls which begin at the old Manchester bridge. The granite is revealed by Brook Run and on Goode Creek and Broad Rock Branch east and south of Clopton. It appears in a small outcrop in the west bank of James River just below the mouth of Goode Creek and is exposed at intervals in the terrace slopes southeast of Manchester. (See Pl. II, *B*.)

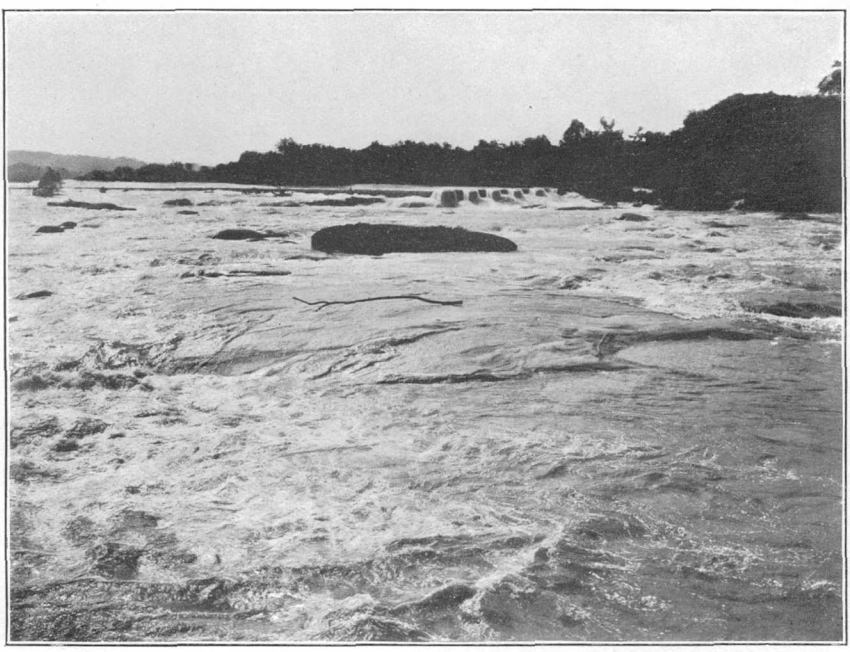
In dredging and deepening the channel it has been found that the rock extends all along the river bottom for several miles below Richmond. Granite has been reported at the following depths in borings in the Richmond region:

Borings reaching granite in the Richmond region.

	Feet.
Hotel Jefferson, Franklin and Jefferson streets	118
Murphy's Hotel, Broad and Eighth streets	140
Richmond Apartments, Ninth and Grace streets	140
Chesterfield Apartments, Franklin and Shafter streets	95
Kingan Slaughterhouse	90
Kingan & Co., Fifteenth and Carey streets	12
Home Brewery, Harrison and Clay streets	98
Merchants Cold Storage, Sixth and Byrd streets	69½
Ginter Park	165
Bellevue Park	85
Paul Ice Factory, Manchester	12½
Westhampton Park	120



A. THE LAFAYETTE PLAIN NEAR RICHMOND, VA.



B. JAMES RIVER FALLING OVER GRANITE LEDGES ABOVE RICHMOND, VA.

In some of these records, notably the last, the figures given denote depth to "hard rock," the overlying decomposed granite being disregarded by the driller. Some years ago a small outcrop of granite with quartz veins was visible in the west bank of Shockoe Creek just south of Marshall Street. Rogers also referred to one of hornblende granite to the left (north) of the crossing of Main Street. Both were overlain by the Patuxent formation and are now covered.

Structural relations.—The granite of the Richmond area appears to be a huge batholith extending far to the north and south. It passes beneath the Triassic overlap to the west and underlies the Coastal Plain to an undetermined distance east. Its contacts with adjoining old rocks have not been studied, and therefore its age is not known. Some portions of this great granite mass show gneissic structure, but this is only noticeable at a few places and is a very subordinate feature about Richmond. Watson [1] has described an occurrence of inclosed blocks of banded granite gneiss in the McCloy quarry, 2 miles south of Manchester. The blocks are several feet wide, and the massive granite cuts across the schistosity and a thin interlaminated mass of pegmatite. Still later dikes of pegmatite cut both rocks. These relations show that the gneiss was developed before the intrusion, and doubtless it is the rock through which the granite was forced. Watson reports an outcrop of gneiss in the old State quarry north of Granite station, but the contact is not exposed. The coarser-grained lighter-colored granite is cut by dikelike masses of the finer-grained darker-colored granite, and both are cut by the narrow pegmatite dikes and a few other later intrusives. Some of the most instructive exposures of these features are in the Smith quarry, on the south bank of James River, 2 miles above Richmond. As described by Watson, there are here several intrusions of the dark finer-grained rock in the coarser granite, and at one point masses of the latter are included. Narrow pegmatite dikes cut across the contact at several places in this quarry.

Petrography.—In order to ascertain the mineral character of the granites in the Richmond region, a series of representative samples was collected, mostly from quarries in operation. These were examined under the microscope by E. S. Bastin. All of the granites were found to be closely similar in mineralogic composition, consisting of quartz, feldspars, and biotite in granular aggregation. Quartz and the feldspar known as microcline are the predominant constituents, and there are smaller varying amounts of the feldspars known as orthoclase and oligoclase. The greenish brown mica of the variety known as biotite is present in moderate amount. Various other minerals

[1] Watson, T. L., Granites of the southeastern United States: Bull. U. S. Geol. Survey No. 426, 1910, p. 80.

occur in small proportions. The rocks differ mainly in coarseness, in regularity of grain, and in percentage of the subordinate feldspars. Rock from the McCloy quarry is almost identical with samples from the James River Granite Corporation quarries. Closely similar but somewhat coarser rocks were collected at the McGowan quarry and on the river bank south of Belle Island. Granites from the Wade and the Green quarries are also closely similar. Granites from the McGowan quarry and the quarry near the mouth of Goode Creek are more irregular in texture than the others and characterized by greater abundance of micrographic intergrowths of feldspar and quartz. They therefore show pegmatitic tendencies, though this is hardly apparent in the hand specimens. Incipient gneissic structure appears in some of the specimens.

The rocks collected were very fresh and constituents injurious from the commercial standpoint are practically absent from all.

McCloy quarry: The rock at the McCloy quarry is of granular texture with grains of nearly uniform size averaging about one-half millimeter in diameter. The dominant light-colored minerals are microcline and quartz, with orthoclase subordinate and an occasional grain of oligoclase. The principal dark-colored mineral is greenish-brown biotite. The minor constituents are muscovite, magnetite in small grains, and apatite. Occasional micrographic intergrowths occur at contact of quartz and microcline grains, and secondary muscovite has developed along cleavage cracks in some of the feldspars.

Richmond Granite Co.: This granite is a light-colored rock of somewhat irregular granular structure in which the feldspars are as much as 5 millimeters in length. The average size of grains, however, is about 1½ millimeters. The dominant light-colored minerals are microcline and quartz; and though oligoclase is abundant, it is less in amount than the microcline. The only dark-colored mineral is greenish-brown biotite, but some of the light-colored mica, muscovite, is present.

The rock exhibits signs of slight alteration, for the biotite shows some development of chlorite and the oligoclase is frequently clouded with secondary muscovite and some calcite. The microcline shows very little alteration, but secondary muscovite often forms strips along cleavage cracks in the feldspar. There are occasional grains of epidote which may be primary. The rock differs from most of the other granites in being somewhat coarser and showing a greater abundance of oligoclase.

Wade quarry: The granite at the Wade quarry is of nearly uniform granular texture, and the average size of grain is about 1 millimeter. The dominant light-colored minerals are microcline and quartz, the latter occurring in part as small globules inclosed by the feldspar. There is also some orthoclase and a very small amount of oligo-

clase. The dominant dark-colored mineral is olive-green biotite in flakes, some of which are 4 millimeters in length, though most are less than 2 millimeters. There is a smaller amount of muscovite and a few small crystals of zircon. The quartz and feldspar show some micrographic intergrowths.

The rock is very fresh, though some shreds of secondary muscovite are developed in a few of the feldspars.

Alvin Netherwood quarry, Granite station: The structure of this granite is granular, and the grains are of nearly uniform size, averaging 2 millimeters in diameter, although some of the feldspars are 3 millimeters long. The dominant light-colored minerals are microcline and quartz with orthoclase and oligoclase in subordinate amounts. Olive-green biotite is the only abundant dark-colored mineral. A small amount of muscovite is present, some of it intergrown with biotite, and there are scattered grains of magnetite and original epidote. There is some micrographic intergrowth of feldspar and quartz. Some of the biotite flakes show partial alteration to chlorite, and some secondary muscovite and a little calcite are developed in the feldspars.

Green quarry: The granite at the Green quarry is of granular structure, the grains, which are of nearly uniform size, being about 1 millimeter in diameter. The dominant light-colored minerals are microcline and quartz, and greenish-brown biotite is the only abundant dark-colored constituent. Magnetite, muscovite, apatite, and zircon occur in small amounts. Micrographic intergrowths of quartz and feldspar are occasionally present. Secondary muscovite is developed in many of the feldspars, and some epidote associated with biotite is probably secondary.

James River Granite Corporation: The ordinary granite from the quarry of this company is of uniform grain whose average size is about one-half millimeter. The dominant light-colored minerals are microcline and quartz with oligoclase also moderately abundant. Greenish-brown biotite is the principal dark-colored mineral. Muscovite, magnetite, apatite, and zircon occur in minor proportions. Micrographic intergrowths of quartz and feldspar are present but not abundant. Shreds of secondary muscovite are developed in some of the feldspars.

McGowan quarry: The granite from the McGowan quarry is a beautiful gray stone of uniform texture. Under the microscope it shows considerable variation in the size of the mineral grains, the average size being about 1 millimeter. The dominant light-colored minerals are microcline and quartz, and oligoclase is moderately abundant. Grayish-brown biotite is the only dark-colored mineral. Muscovite, epidote, and zircon also occur in small amount, and the epidote, though generally associated with biotite, has sharp borders

and appears to be an original constituent. Micrographic intergrowths of quartz and feldspar are abundant. Secondary muscovite is developed in some of the feldspars.

Smith quarry: The coarser variety of the granite in the Smith quarry shows much variation in size of the mineral grains, and though the average size of grain is about 1½ millimeters some feldspars are 4 millimeters long and some biotite flakes 3 millimeters. The dominant light-colored minerals are microcline and quartz and considerable oligoclase is also present. Greenish-brown biotite is the principal dark-colored mineral and it is notable that apatite is abundant. Muscovite, magnetite, and zircon occur in smaller amounts. Micrographic intergrowths are moderately abundant. Secondary muscovite and a little calcite develop in some of the feldspars.

The finer-grained rock in the Smith quarry has grains of nearly uniform size, the average diameter being about one-half millimeter. The dominant light-colored minerals are microcline, quartz, and orthoclase. Oligoclase and muscovite occur in smaller amounts. The principal dark-colored mineral is greenish-brown biotite. Apatite, magnetite, zircon, and original epidote occur in scattered grains. Some micrographic intergrowths of quartz and feldspar are present. Secondary muscovite is developed in some of the feldspars. Part of the rock in this quarry shows considerable schistosity.

South end of bridge to Belle Island: A sample of granite from an old small quarry on the south bank of James River, opposite Belle Island, has the common granular structure, with grains of nearly uniform size averaging about 1 millimeter in diameter. The dominant light-colored minerals are microcline and quartz, with orthoclase and oligoclase subordinate. The principal dark-colored mineral is greenish-brown biotite. Magnetite and apatite occur in scattered grains. Micrographic intergrowths of feldspar and quartz are present but not abundant. Secondary muscovite and some calcite are abundant in many of the feldspars.

Quarry on west bank of James River at mouth of Goode Creek: This granite has an irregular granular structure, the grains varying greatly in size; the average diameter is about one-half millimeter. The dominant light-colored minerals are microcline and quartz with muscovite and oligoclase subordinate. The principal dark-colored mineral is greenish-brown biotite. Apatite and epidote occur as scattered grains. Secondary muscovite develops in some of the feldspars.

Analyses.—Analyses of composite samples of various kinds of granite have been made by William M. Thornton, jr., in the laboratory of the Virginia Geological Survey.[1] They are as follows:

[1] Bull. Virginia Geol. Survey No. 1A, Ann. Rept. of mineral production of Virginia for 1908, p. 81.

Analyses of granites from Richmond area.

	1	2	3	4	5
Silica (SiO_2)	72.27	71.19	70.83	69.44	69.29
Alumina (Al_2O_3)	14.30	14.01	12.70	15.46	14.07
Ferric oxide (Fe_2O_3)	1.16	1.66	2.67	1.31	2.59
Ferrous oxide (FeO)	.97	1.29	1.36	1.43	2.03
Magnesia (MgO)	.70	.44	.53	1.01	1.32
Lime (CaO)	1.56	2.04	1.88	2.11	2.76
Soda (Na_2O)	3.46	3.56	3.49	3.97	2.89
Potash (K_2O)	5.00	4.45	4.83	4.25	2.87
Water to 110°C	.04	.04	.07	.07	.06
Water 110°C	.25	.33	.34	.29	.37
Titanic oxide (TiO_2)	.31	.35	.41	.48	.50
Manganese oxide (MnO)	Trace	.02	.03	.03	.08
Carbon dioxide (CO_2)	.21	Trace.	Trace.	Trace.	Trace.
Phosphoric acid (P_2O_5)	.02	.34	.33	.22	.26
	100.25	99.72	99.47	100.07	99.09

1. Westham quarries, Chesterfield County, Va., 4½ miles west of Richmond. Medium textured and medium gray biotite granites.
2. McGowan, Netherwood, and Donald quarries, Chesterfield County, and Mitchell and Copeland quarries. Fine-grained dark blue-gray biotite granites.
3. Netherwood, Old Dominion Granite Development Co., Kremm and Middendorf quarries, Chesterfield County. Medium coarse textured and medium gray biotite granites.
4. McIntosh quarry, Chesterfield County, 5 miles west of Richmond, Va. Medium textured and medium gray biotite.
5. Middendorf quarry near Manchester. Medium coarse textured gray biotite granite.

POTOMAC GROUP.

PATUXENT FORMATION.

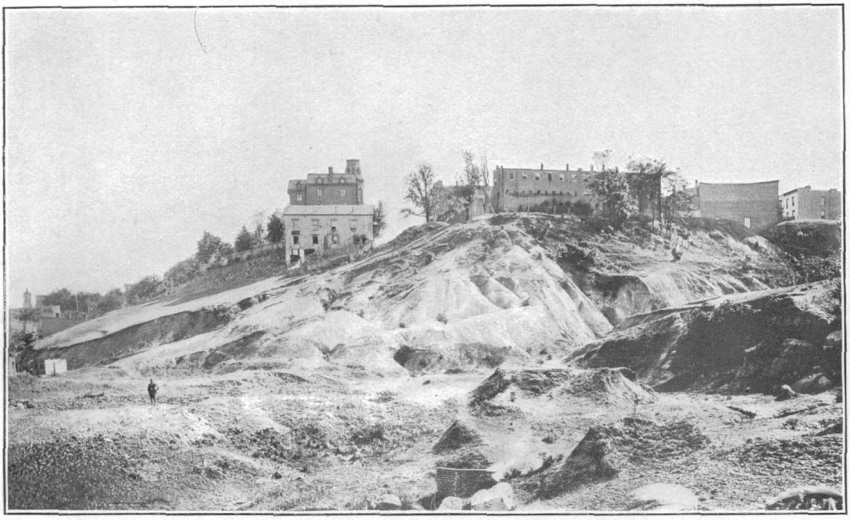
General relations and character.—The Patuxent formation underlies the eastern part of Richmond and the region east and south. Its western margin probably is near the capitol building, where it abuts against an upslope of granite, as shown in the cross-section (Pl. I). Its outcrop extends along the east bank of James River to the south from the mouth of Shockoe Creek, and there are extensive exposures in the river bluffs and along Shockoe and Gillis creeks. In this area the formation is less than 50 feet thick, but doubtless the thickness increases somewhat in the underground extension of the formation to the eastward. It is possible that the Patuxent formation as here described and mapped may include a representative of the Patapsco formation at the top, but it is believed that all of the deposits belong to the Patuxent.

The materials of the Patuxent formation are mainly sand and gravel. The sand consists largely of angular grains of quartz, but it is generally mixed with feldspar in a more or less decomposed condition. This mixture is commonly known as arkose. Considerable mica is present in places. Clay occurs in streaks and admixture with the sand and also in the form of pebbles. The character of the deposit is so variable that no two exposures present the same succession, but the arkosic sand containing pebbles and bowlders predominates. Most portions of the exposures show strong cross-bedding and rapid changes in the character of the material. Some of it is consolidated into a soft sandstone which disintegrates rapidly on exposure. The

gravel and bowlders occur in irregular deposits through the sands and consist largely of quartz and quartzite with granites and other varieties of crystalline rocks.

Local features.—The Patuxent formation appears most extensively in the face of the low bluff just south of Carey Street from Twenty-fourth Street to Rochelle Street and thence in slopes east to Williamsburg Avenue and Thirty-second Street. East of Twenty-fourth Street it rises from 3 to 5 feet above the railroad to a contact with the Aquia formation at 20 feet above sea level. The material is a coarse light gray and buff cross-bedded arkosic sand containing some bowlders. One bowlder bed 3 feet below the base of the Aquia formation is 2 feet thick and 25 feet long. The formation rises higher east of Twenty-eighth Street, cutting off the Aquia beds, and is well exposed in deep cuts of the Chesapeake & Ohio Railway extending to Rocketts Avenue and beyond. The cut exposes 25 feet in its deepest part, as shown in Plate III, *B*. The arkosic sand contains pebbles of clay and quartzite. This exposure continues eastward to Thirty-second Street, where there is an excellent outcrop of the contact of the Patuxent and Aquia formations in and near a small creek which crosses the Williamsburg Road at Thirty-second Street. The formation appears again in a large gravel pit a few rods farther south on the south bank of Gillis Creek. This pit is a few yards above the crossing of the Chesapeake & Ohio Railway. The formation here consists of the common cross-bedded arkosic sand of gray color containing pebbles and bowlders. It is overlain by the Columbia group, consisting largely of bowlders and pebbles. The features at this place are shown in Plate V, *B*, in which the Columbia-Patuxent contact is nearly on a level with the heads of the men. Farther up Gillis Creek there are scattered outcrops of the formation, notably at the bridge of the National Cemetery Road, where the exposure is continuous for some distance. The materials are light-gray arkosic sand, with scattered deposits of pebbles. Its surface rises somewhat up stream from the bridge, but in about one-half mile it passes beneath the Aquia formation in the bottom of the creek. The contact is covered. There was formerly a 15-foot bluff of the formation between the creek and the road on the south side of Gillis Creek, just east of the crossing of the Williamsburg Road. It contained bowlders of green clay and was capped by the deposits of the Columbia group.

The Patuxent formation is extensively exposed along the river bank in Rocketts from the cedar works to the wharfs near the mouth of Almond Creek—a distance of about three-fourths of a mile. The best exposures are at Louisiana and Orleans streets, where the formation rises about 30 feet above the river to the base of the Columbia group, which caps the terrace at Rocketts. According to well-borings its base is 15 feet below sea level where the granite is found.



A. WEST SLOPE OF SHOCKOE CREEK VALLEY, NEAR INTERSECTION OF TWELFTH AND LEIGH STREETS, LOOKING SOUTHWEST. CALVERT FORMATION CAPPED BY LAFAYETTE.

B. PATUXENT FORMATION IN CUT OF CHESAPEAKE & OHIO RAILWAY AT BRIDGE OF MAIN STREET AT LESTER STREET, RICHMOND, VA.

The material is the typical arkosic sand, with pebbly anb powldery streaks. One thin layer of carbonaceous sandy shale occurs in the formation in this exposure.

Two small exposures appear on the east side of Almond Creek, one on the road and another at the pit for molding sand east of the brickyards. Here the Patuxent is capped by the Aquia formation 3 to 5 feet above the bottom of the valley. The principal exposure of the formation in the bank of Shockoe Creek extends from a point near the intersection of Eleventh and Balding streets nearly to the Turpin-Washington Street crossing. It exhibits from 5 to 16 feet of cross-bedded arkosic sand, with bowlder beds in part conglomeratic. It is overlain by deposits of the Columbia group. Many years ago, according to Prof. Rogers, 8 feet of the formation were exposed in a low knoll in the bottom of the valley just north of Main Street. There was a mill at this place and the beds were cut by the race, the underlying granite outcropping in the creek nearby. These features have long since been covered. A small exposure of Patuxent formation lying on granite was visible some years ago on the west bank of Shockoe Creek just below Marshall Street. The thickness exposed was 8 feet and the material a gray and buff arkosic sand, with pebbles scattered through it. At the base is a 6-foot layer of conglomerate. Another exposure appeared on the west bank of the creek at Clay Street, capped by weathered Aquia formation with a pebbly bed at the base such as commonly occurs. The contact is about 32 feet above sea level. A small exposure was noted in a sewer near the corner of Turpin and Thirteenth streets, capped by deposits of the Columbia group. This is a short distance south of the large exposure extending along the creek bank nearly to Balding Street. Just above the point at which the Seaboard Air Line Railway crosses Shockoe Creek at Fourteenth Street below Turpin Street, there is a ledge of brown conglomerate 30 feet long, 20 feet wide, and 2 feet thick. Though it is probably the base of the Columbia, it may be the Patuxent. The same doubt exists as to a gravel bed at the bridge. The Patuxent formation was reported in a well at the Exchange Hotel, on Broad and Thirteenth streets. This well penetrated a bowlder bed at a depth of 77 feet, probably at the base of the Aquia formation, lying on Patuxent beds extending to the bottom of the well at a depth of 84 feet.

PAMUNKEY GROUP.

AQUIA FORMATION.

General relations and character.—The only formation of the Pamunkey group which is present in the Richmond area is the Aquia. The western edge of the Aquia formation extends into the central part of Richmond, where it becomes thinner against the rising slope of

the granite. Probably it overlaps a short distance beyond the edge of the Patuxent formation not far west of the capitol building. The formation is cut through by the lower parts of valleys of Shockoe, Gillis, and Almond creeks, in which it is exposed at intervals lying on the Patuxent formation. It also appears in various gullies along the east bank of James River south of Almond Creek. The principal material is a soft sand, mostly of a mottled gray and black color, which weathers to a reddish buff tint on the oxidation of the contained iron. At the base is a bed of gravel about a foot thick. The greatest thickness of the formation, so far as could be ascertained, is 25 feet, but in places it is only 12 to 15 feet thick.

Shockoe Valley.—In ravines on the west side of Shockoe Creek valley, W. B. Rogers[1] reported the following beds in the Aquia formation:

> The lower portion, from 6 to 10 feet thick, consists of a sand mixed with a small proportion of clay of yellowish gray color mottled with brown. It contains greensand (glauconite) grains irregularly scattered through it. Abundant casts of *Cardita planicosta, Turritella mortoni,* and other forms, in part with the shells in very soft condition. Next above is a member consisting of a mixture of dark olive or greenish clay and sand containing grains and granules of greensand. This bed, which is about 12 feet thick at most, abounds in fish teeth, especially of genus *Otodus* and *Ondontapis,* and coprolites, mostly small. Next above is a second sandy bed of light-yellowish tint mottled with brown and barred by thin irony layers. It is also highly fossiliferous. Some distance up the ravine it is 8 feet thick, but it thins out to the east towards the mouth of the hollow, and its upper surface exhibits evidence of irregular denudation prior to the deposition of the deposits of Miocene age which lie on it.

The formation is well exposed at intervals along the west side of Shockoe Valley, notably in the three deep gullies between Leigh Street and the locomotive works at Seventh Street crossing, and also in the railroad cut near the line of Eleventh Street (extended). There is a member of dark sand at the top lying on a harder layer containing considerable iron. The latter weathers to a buff color and grades down into 15 to 20 feet of dark-gray sands containing considerable glauconite and many fossils, mostly in the form of casts. The total thickness is about 25 feet. The upper surface appears to rise somewhat in the vicinity of Eighth Street. In the deep gully on the line of Eighth Street the upper 12 feet of the formation is well exposed, consisting of dark sand overlain unconformably by clay of the Calvert formation. There are exposures of Aquia formation in the bank of Shockoe Creek, notably on the line of Eighth and Ninth streets and halfway between Tenth and Eleventh. The formation extends up the creek bed to a point a rod or two above the first main forks (Seventh Street), but the contact here is concealed by filling. A small outcrop of the Aquia formation is visible on Valley Street on the east side of Shockoe Valley near the line of Fourteenth Street extended northward.

[1] Proc. Boston Soc. Nat. Hist., vol. 7, pp. 61-62, 1861.

A small projection of the Aquia formation appears in the bluff south of Carey Street just east of Twenty-fourth Street and extends for 200 to 300 yards. About 10 feet of the formation are exposed, lying on the irregular surface of the Patuxent formation at an altitude of 20 feet, and capped by deposits of the Columbia group and street filling. The material is greenish-gray, mottled sand containing gravel and bowlders in the lower 2 or 3 feet, the coarsest part being at the bottom. A rise of the Patuxent surface to the east cuts off the formation near Twenty-sixth Street.

Twenty-eighth Street to Gillis Creek.—The Aquia formation is extensively exposed along the base of the hills on Main Street and Williamsburg Avenue from Twenty-eighth Street east to Gillis Creek. On the northwest corner of Williamsburg Avenue and Thirtieth Street, just above the street level, are 3 feet of coarse brown sand and 5 feet of coarser sand of green color variegated with buff blotchings, both typical of the formation in its weathered condition. On its surface lies the Calvert formation, of which the base consists of clay with sandy streaks, clay breccia and ironstone layers. Main Street rises to the top of the Aquia formation between Twenty-seventh and Twenty-eighth streets, where exposures cease. Williamsburg Avenue rises to the top, or very near to it, at Thirty-first Street, and as it descends to the southeast this avenue cuts into the formation until between Thirty-first and Thirty-second streets the full thickness of 25 feet is exposed. The material is sand of mottled brown and green color with a 10 to 20 inch deposit of bowlders and pebbles at the base. Next below is exposed 4 feet of arkose belonging to the Patuxent formation. The top of the Aquia formation extends north from this point up the depression followed by the old railroad line to a point within a few yards of the mouth of the tunnel, or approximately at the intersection of Thirtieth and Grace streets. The formation contains a zone of iron concretions about a foot below the Calvert contact. It is all somewhat glauconitic.

There are only a few exposures of Aquia formation in Gillis Creek valley. There was formerly a pit for sand in the flat west of the crossing of the National Cemetery Road by the railroad and west of a small gully. There are several pits for molding sand and overlying gravels south of the National Cemetery Road south of the creek. Its basal gravelly bed is in contact with Patuxent formation a half mile above that road. The formation is exposed in stream cuts at the dam, where it is capped by deposits of the Columbia group. It does not quite reach the mouth of Stony Run.

Almond Creek southward.—The Aquia formation is well exposed in molding sand pits on the east bank of Almond Creek just southeast of Rocketts, where the thickness is 15 feet from Patuxent to Calvert contacts. The material is gray and greenish sand mottled with buff.

It contains a small amount of clay. At the base for about a foot it is filled with gravel. This material appears again a quarter of a mile farther down the creek and on the same side in a pit by the side of the road which passes through the brickyards and joins the Osborn Road. This exposure can be traced at intervals down the east bank of James River, but lies back some distance in ravines heading in the plateau. There is a sand near the top of the bank at the brickyards on Maury Street near Fourteenth in Manchester which is very like the Aquia in appearance.

CHESAPEAKE GROUP

CALVERT FORMATION.

General relations and character.—The plateau at Richmond and to the north, east, and southeast is underlain by the dark clay and sand of the Calvert formation, the only formation of the Chesapeake group which is present in the Richmond area. Its western margin lies under the Lafayette formation along a line extending north from Hollywood Cemetery and passing near the Hermitage Road. Along its western edge it overlaps on to the granite, but to the east it lies on the Aquia formation. It also thickens greatly to the east, for in a well at the Jefferson Hotel it is 75 feet thick, in Church Hill tunnel it is 85 feet thick, and in the region south of Gillis Creek it exceeds 80 feet. The general relations are shown in the section in Plate I. Its base is at an altitude of 150 feet in Brook Run, northwest of Brook Hill, at 80 feet at foot of Pine Street, 62 feet at Jefferson Hotel, 55 feet on Williamsburg Avenue near Thirtieth, 50 feet on Gillis Creek, and 30 feet on south bank of Almond Creek, but it appears to rise slightly farther south. The small showing of the formation which appears in the cut of the Belt Line Railroad, one-half mile northwest of Clopton, is at an altitude of 175 feet.

The most extensive exposure of the Calvert formation is in the steep slopes of the valley of Shockoe Creek, beginning at Franklin Street and extending continuously far to the north and west up the main valley and its branches (Pl. III, *B*). Its basal contact on the Aquia formation is above the valley bottom to Seventh Street, where the top of the latter formation passes underground. It extends up Bacons Quarter Branch to a point within a few yards of the city boundary at Lombardy Street, where its top passes beneath the conglomerate at the base of the Lafayette formation. Apparently it rises again from beneath this conglomerate and is exposed in the creek at two or three points about one-quarter of a mile east of the crossing of Hermitage Road. There are extensive exposures of the formation along the east slope of Shockoe Valley and extending along the base of the plateau on which Chimborazo Park is situated into Gillis Creek valley. Some of the largest outcrops are at Twenty-

first and Grace streets, Twentieth and Marshall streets, and along Lester Street and Williamsburg Avenue east from Twenty-seventh Street.

The principal material is dark-gray clay, which merges into deposits of very fine laminated sand of buff color. In the lower beds there is an admixture of diatom remains in variable proportions, notably at a horizon from 5 to 20 feet above the base. Some of the material contains so large a proportion of these diatoms that it may be classed as "diatomaceous earth," which has some economic value. In its unweathered condition the clay of the Calvert formation varies in tint from pale dove color, through lead gray, nearly to olive green. On weathering, various shades of color result. The portions rich in diatom remains become nearly pure white, and other portions become brownish gray, yellowish brown, or buff and yellow, depending upon the degree of oxidation of iron and amount of carbonaceous matter. The material is very massive when fresh, but after weathering it shows much banding and lamination. Some of this banding is due to alternations of sandy beds with nearly pure clay. There is considerable iron pyrites in the deposits, and on weathering this gives rise to an acidic iron solution, which in some places stains the beds yellow and in others bleaches out the color to light tints. Much of the clay has a sulphurous odor from this source. Shells and impressions of shells occur in large numbers in most of the beds.

The diatoms occur mainly in a stratum about 20 feet thick, beginning some 4 feet above the base of the formation, and more sparingly higher in the formation. The richer deposits occur mostly in streaks and irregular masses, grading into clay that contains a greatly diminished proportion. It is a mistaken idea that there is a thick continuous deposit of high-grade diatomaceous earth underlying Richmond. In Church Hill tunnel, according to Coryell, the formation is 85 feet thick, and the diatoms were in large proportion 50 feet above the base, whereas the basal and top portions were nearly barren of them (Pl. IV, *A*, and fig. 1).

The diatomaceous member is overlain by 20 to 50 feet of gray clay containing sand in general admixture and in varying proportions in different beds, but the character of this material is exceedingly variable. The following description of the formation, especially the diatom-bearing member, is from the report of W. B. Rogers, as State geologist of Virginia for 1840:

> The material in question [diatomaceous earth], composing a thick stratum between beds of sand and clay, is more or less mingled with them, particularly in the vicinity of its bounding surface. But throughout most of its thickness it presents a very fine texture, admitting of being bruised by the fingers into an almost impalpable powder, and singularly free from gritty particles. Its color is a very light gray to white, but the fragments into which it spontaneously divides at the exposed surface of the stratum often present externally a slight ocherous tinge. It is decidedly, though sometimes

indistinctly, laminated, the planes of the thin flakes or sheets being horizontal. When moistened, it displays considerable tenacity, and hence has hitherto been regarded as a fine clay or fuller's earth. Of all its peculiarities, however, capable of being readily discovered, its great lightness is the most extraordinary and characteristic. When quite free from moisture, a pure specimen has a specific gravity of only 0.33, or one-third the weight of water, bulk for bulk.

It is composed almost entirely of microscopic remains of numerous forms of diatoms and rhizopods, many of which are round or oblong disks or cylinders. The former are mostly from one one-hundredth to one six-hundredth of an inch in diameter, and the latter from one three-hundredth to one four-hundredth of an inch long and one twelve-hundredth to one sixteen-hundredth of an inch in diameter, but there are numerous smaller ones. They are marked with many intricate features or divisions of the most remarkable delicacy of form. The number of individuals in a cubic foot is many millions.

This stratum shows itself at nearly the same level on the hillside and in the ravines on both sides of the valley of Shockoe Creek and may be traced on the Shockoe Hill side of the valley without interruption as far as the crossing of the Hanover Road toward the head of the valley and near Turner's mill. From a point on the slope of Church Hill a little beyond Butchertown, commanding a view of the hills and ravines from the poorhouse down, it is easy to trace the broad belt of this deposit by its surface being comparatively deprived of herbage and presenting a white and barren aspect. The thickness of the stratum varies at different points from 12 to 25 feet, the most striking exposures being those met with in the ravine behind the Monumental Church and that between Col. Ambler's and the French Garden. The same or a very similar order is observed in the exposures visible on the opposite side of the valley along the slope of Church Hill. At the bottom of the ravine we see the upper portion of the Eocene and over this the infusorial stratum showing itself plainly and of great thickness at the following points:

1st. Just back of Butchertown on the two roads that extend up the hill.

2d. At the foot of the abrupt base bank which has been cut into north of Main Street on Church Hill and thence south nearly to the next street.

Indeed, along the slope of Church Hill, on the other side of the valley, this stratum may be found in all the ravines and cuttings at the proper level.

Above the infusorial stratum are lead-colored and ocherous sands and clays sometimes nearly resembling it in color but readily distinguished by their greater heaviness. Those which belong to the Miocene division of the Tertiary are remarkable for containing near and for some distance above the infusorial stratum numerous vegetable markings of a vague description, as well as many well-defined impressions of leaves and stems; and toward the top impressions of scallop shells (*Pecten*) and other Miocene fossils. Among the numerous points at which these strata are exposed, the following may be mentioned as interesting and easy of access:

1st. On Governor Street as you descend Main Street, where the impressions of shells are very numerous.

2d. The steep bank opposite the synagogue. Here the clays near the base abound in vegetable impressions, among which are admirably defined leaves. Toward the top the more sandy material contains impressions of pectens.

3d. On Church Hill back of Mr. Van Lew's garden and the bare bank exposed along the valley side of the hill behind Mr. Greaner's dwelling. The base of this bank is on a level with the top of the infusorial bed.

A section in the principal ravine on the west side of the valley of Shockoe Creek is given as follows by Rogers:

At base 3 feet of "lead-colored heavy clay with greenish tinge," then 20 feet of infusorial stratum, 6 feet of greenish-brown and lead-colored clays with vegetable impressions, and 14 feet of more sandy stratum of mottled gray and yellowish-brown vegetable impressions and prints of pectens. In a later description by Rogers, in 1859,[1] he stated that the "infusorial deposit" varies in thickness from 20 to 30 feet on the north side of Shockoe Creek valley and 50 feet on the Church Hill side. It is separated from the Eocene by a thin deposit of whitish and sometimes ocherous clay mingling toward the top with the lighter material of the infusorial stratum. The beds overlying the latter are a series of strata consisting of various intermixtures of clay and sand, of which the lower is generally a compact, light-colored clay, the next a bluish or grayish, more arenaceous mass, and the uppermost an argillaceous stratum of light-brown and mottled appearance. The total thickness of this series is about 25 feet. There are many fossils, among the most common of which are *Fusus quadricostatus*, *Panopæa reflexa*, and Miocene species of *Pecten*, *Arca*, *Crassitella*, *Cytherea*, *Venus*, *Astarte*, *Turritella*, etc. In the lower dark-colored stratum are "stems and woody pieces which from microscopic indications seem to be coniferous, while on the argillaceous layers both beneath and above are prints of dicotyledonous plants." The diatoms are microscopic forms of plants which live in salt water as well as fresh, and have the power of secreting silica to form their shell or test. When the plant dies these minute structures of silica accumulate on the bottom, but undoubtedly a very long period was required for the formation of the thick beds which we now find, especially the purer layers, which have but little admixture of clay or sand. The diatom tests are very beautiful objects under the microscope.

List of diatoms.—Stodder has given a list of the species of diatoms from various horizons from samples collected in a ravine on the west side of Shockoe Hill.[2] Four horizons were selected—the first, 5 feet below the surface of the exposure; the second, 11 feet below; the third, 14 feet below; and the last on the north side of the ravine "40 feet below the top, from a bed apparently the continuation of the 14-foot bed on the opposite side, the hill being higher on the north side." All the specimens are similar in appearance excepting those from the lower bed, which are much darker. The material is very like clay, of light-drab color and very low specific gravity. The upper bed has a smaller proportion of diatoms, about 20 per cent, but they are in more perfect condition, whereas in the deeper beds they are more broken. The lower layers contain 50 to 80 per cent of organic forms, of which diatoms constitute by far the greater part. The other

[1] Proc. Boston Soc. Nat. Hist., vol. 7, 1861, pp. 59–64.
[2] Idem, vol. 18, 1877, pp. 206–209.

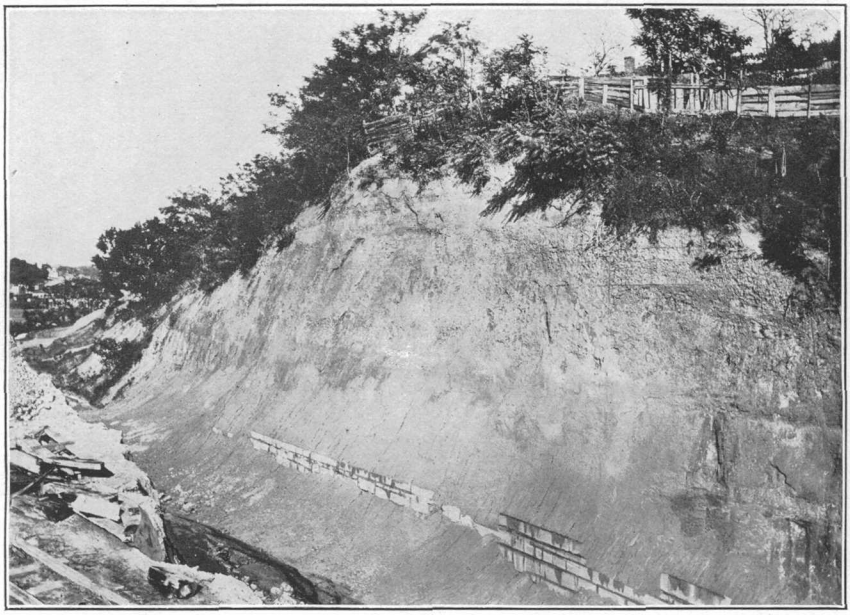
material is clay and fine silt. The following table shows distribution of species, and it will be noted that the principal difference is in the upper or 5-foot layer, for it lacks many of the genera or species of the lower strata:

Diatoms in the Miocene deposit at Richmond, Va.

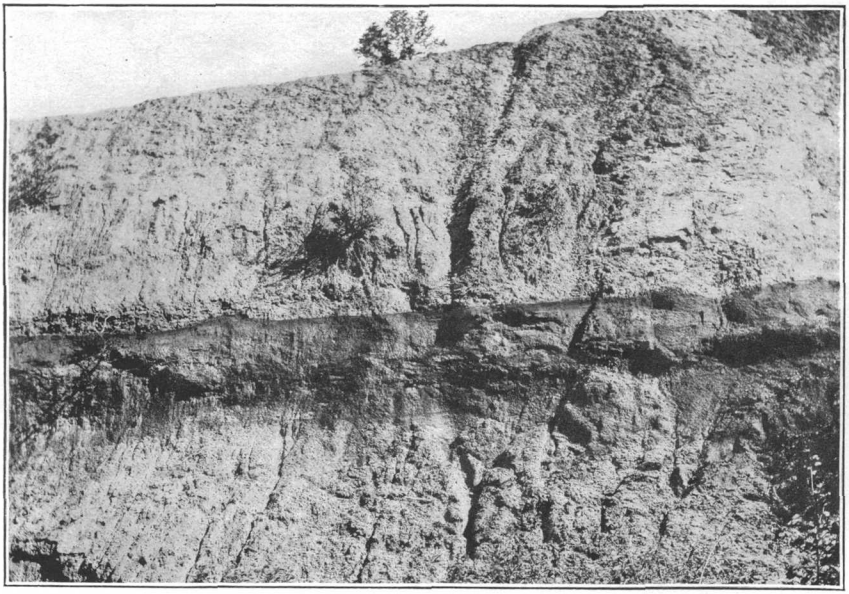
	5 feet.	11 feet.	14 feet.	40 feet.
DIATOMACEÆ.				
Actinoptychus senarius		×		×
biternarius	×	×		
Omphalopelta punctatus	×	×		
versicolor		×		
Actinocyclus ehrenberghii			×	
Coscinodiscus radiolatus		×		
punctatus, oval and spherical varieties	×	×	×	×
lineatus		×	×	
velatus	×	×		
marginatus	×	×		
radiatus		×	×	
gigas	×	×	×	×
oculis-iridis	×	×	×	
perforatus	×			
centralis			×	
subtilis		×		
Systephania corona		×	×	×
Aulacodiscus crux	×			
Craspedodiscus coscinodiscus	×	×	×	×
Asterolampra brebissonii Greg		×	×	
Eupodiscus rogersii	×			
Endictya oceanica				×
Pyxidicula aculeata		×		
Stephanopyxis diadema		×		×
apendiculata		×	×	
Xanthiopyxis globosa		×		×
hirsuta		×		
oblonga				
Rizosolenia americana	×	×	×	×
Goniothecum odontidium	×	×	×	×
rogersii	×	×	×	×
Dicladia capreolus			×	
Chætocero sp		×		×
Biddulphia toumeyii	×	×	×	×
Triceratium reticulum		×		
undulatum		×		
condeconum		×		×
obtusum	×		×	×
marylandicum		×	×	×
Mastogonia actinoptychus	×			
Rhaphoneis amphicerus		×		
Grammatophora marina		×		
africana		×		
Navicula (Pinnularia) perigrina		×	×	
viridis		×	×	×
Navicula viridula				×
Pleurosigma=Nav. sigma Eh., very like P. angulatum		×	×	×
Stephanogonia polygonia		×		×
Orthosira marina W. S.=Galionella sulcata Eh.	×	×		
Fragilaria pinnata		×		
RHIZOPODS.				
Actiniscеæ:				
Actiniscus pentasterias	×	×		
Dictyocha crux	×			
fibula	×			
Mesocenia diodon	×			
Polycistinæ, various	×			×
Phytolitharia Eh., Spongolithis accicularis, S. caputserpentis; spines of Polycistinæ, Acanthometra and others	×	×	×	×

It has not been thought advisable to attempt to identify all of Ehrenberg's species, as his plan was to found a species upon any variation in the number of rays in the circular forms of the Diatomaceæ, a principle now generally rejected.

One striking fact is the great abundance in all the layers of *Galionella sulcata* Eh.= *Orthosira marina*. W. Smith, which is more numerous in some slides than all the other forms together.



A. CALVERT FORMATION IN CUT NEAR ELEVENTH AND TURPIN STREETS, RICHMOND, VA. DIATOM-BEARING CLAYS.



B. CONTACT OF CALVERT AND AQUIA FORMATIONS IN GULLY AT TWELFTH AND LEIGH STREETS, RICHMOND, VA. LOOKING SOUTH.

Basal contact.—The contact of the Calvert and Aquia formations is exposed at many places along the west side of Shockoe Valley from Seventh Street crossing to Broad Street, and although not everywhere equally distinct there is marked unconformity throughout. The top of the Aquia formation is irregularly eroded and faintly channeled with depressions in places an inch or two deep. Some of the dark sand of the Aquia formation is mixed with the first deposits of the Calvert formation.

An exposure of the contact beginning a few yards northwest of the intersection of Leigh and Thirteenth streets extends into the gully a few rods north of there and thence for some distance along the foot of the slope by Twelfth and Turpin streets. (See Pl. IV, *B*.) Near the top of the Aquia formation is a hard layer, in part ferruginous, 3 to 5 inches thick, grading up into 2 feet of dark-gray sand with considerable clay admixture. On the irregularly eroded surface of the latter lies the base of the Calvert formation, a gray clay with many dark sand grains and scattered quartz pebbles. In places where the basal Calvert contains much dark sand, the contact is not very distinct.

In the cut of the Seaboard Air Line Railway, on the west side of Shockoe Creek near the line of Eleventh Street, the contact is exposed for 125 feet about 10 feet above the tracks. It is somewhat indistinct owing to the dark color and sandy nature of the basal member of the Calvert formation for about a foot above the contact. Many scattered pebbles occur in the deposit, and it weathers lighter than the underlying Aquia formation. At the top of the latter are 2 feet of dark sand, grading down into a hard layer 8 inches to 1 foot thick, which weathers to a buff or yellow color. In this vicinity the diatoms extend down to within a short distance of the contact apparently because the plane of contact rises somewhat. There are extensive exposures of the Calvert and underlying beds in the large gully from the west which empties into Shockoe Creek near Eleventh and Balding streets. The basal contact is clearly exhibited and the diatom-bearing deposits extend nearly to the base of the Calvert formation. At the base there is, as at other places, considerable sand and scattered pebbles. The contact plane presents many small irregularities and in general it shows a slight rise to the north and west probably some of it crossing the Calvert strata.

The Calvert-Aquia contact crosses Shockoe Creek just above the line of Seventh Street somewhat above the main forks of the creek, but it is covered by filling. It is well exposed for about 100 yards in a gully on the west side of the valley a few rods south of this place or on a line with Eighth Street. Here it is particularly distinct, for at the top of the Aquia formation is 12 feet of dark-colored sand and the plane of contact is notably irregular. The gully is cut deep

into overlying Calvert beds which are diatomaceous down nearly to their base. The basal bed is sandy and contains many small scattered pebbles of quartz and grains of glauconite.

The Calvert formation and its basal contact are well exposed at the southeast end of Main Street at its junction with Williamsburg Avenue at Twenty-eighth Street, and extending around the south end of the high bluff to the old railroad tunnel. The contact is 8 feet above the street grade at Thirtieth Street and Williamsburg Avenue, or at about 55 feet above sea level. The brown and green mottled sands of the Aquia formation are planed off nearly smooth, and on them lies a thin deposit of clay containing sand layers and streaks and considerable ironstone. Some brecciated masses of clay occur in this layer. Next above is a 4-foot bed of very stiff blue-gray clay grading sharply into compact clays containing a large proportion of diatom remains, of which 50 feet or more are exposed up

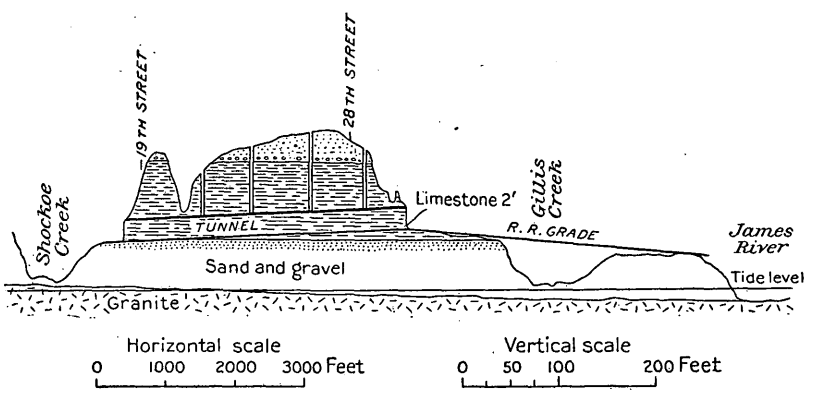
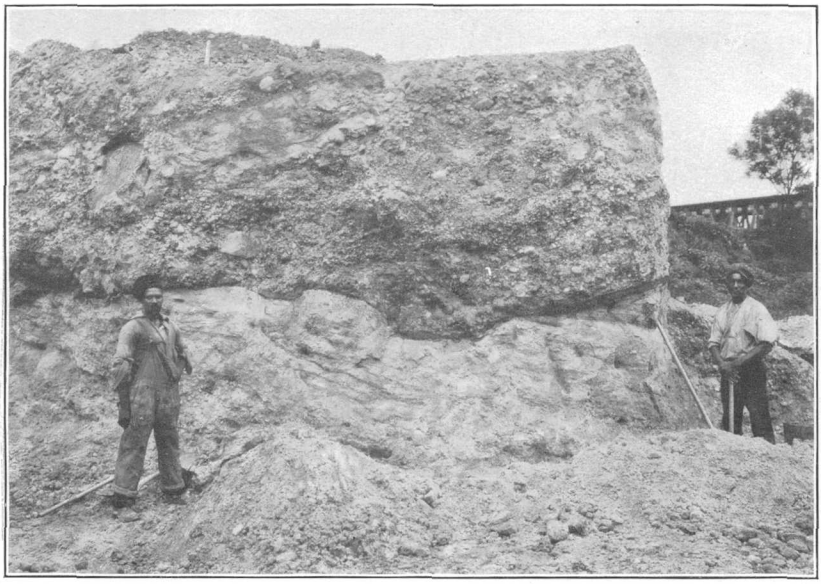


FIGURE 1.—Section across Church Hill, Richmond, Va., along line of old tunnel, Chesapeake & Ohio Railway after M. Coryell. The horizontal broken lines represent Calvert formation; the overlying material is Lafayette gravelly orange sand; below is Aquia sand lying on Patuxent sand and gravel.

to the capping of Lafayette formation on the plateau. Williamsburg Avenue rises very nearly to the base of the Calvert formation at Thirty-first Street, apparently within 2 feet. The contact extends eastward and then north up the depression followed by the old line of the Chesapeake & Ohio Railway to a point within a few yards of the mouth of the tunnel. It is very smooth, has slight local irregularities, and dips gently to the east at a very low rate. The basal bed is a dark, tough, sticky clay about 4 feet thick. Its basal portion contains some gray sand and glauconite grains from the underlying Aquia formation. The old tunnel is entirely in the basal portion of the Calvert formation, as shown in figure 1.

The formation is largely exposed on the north side of the valley of Gillis Creek in banks 10 to 50 feet high. The material is dark clay containing diatom remains which are in considerable proportion in some beds. The richly diatomaceous material weathers out in soft

A. CALVERT FORMATION ON GRANITE ON NORTH BANK OF JAMES RIVER, NEAR FOOT OF PINE STREET, RICHMOND, VA.



B. COLUMBIA GROUP ON PATUXENT FORMATION ON SOUTH BANK OF GILLIS CREEK, NEAR ITS MOUTH, RICHMOND, VA.

chalky masses of light weight and nearly pure white color. The basal contact is exposed just north of the National Cemetery Road in the bed of a small creek near the line of the prolongation of Broad Street or just west of the point where that road crosses Gillis Creek. The contact is near the level of the road. The Calvert formation is well exposed on the south side of the valley from the National Cemetery Road northward and they extend down to the creek a short distance west of the main road crossing at the mouth of Stony Run.

Western margin.—The western margin of the Calvert formation extends across the edges of the Aquia and Patuxent formations, as shown in the section in Plate I, to an irregular line extending along the east side of Hollywood Cemetery and near the Hermitage Road to a point not far west of Brook Hill. Possibly in the higher part of the western portion of Richmond it extends some distance west of the line, as far even as Acca. There are exposures of the thin edge of the formation lying on granite in the railroad cuts on the north bank of the river at the foot of Pine and Laurel streets. A view of a portion of the exposure is shown in Plate V, *A*.

The material at this place is fine, loamy sand containing a few pebbles and quartz fragments in its basal portion. The thickness is about 6 feet. The contact is very irregular, being marked by channels or pot holes, one of which is shown in Plate V, *A*. Nearer Pine Street there is considerable gravel in the basal part. The formation thins out to the west, but owing to the presence of talus it was not possible to locate its margin; it may extend into Hollywood Cemetery back some distance from the river. The formation thickens to the east and 20 feet appear in the bank near the foot of First Street. It was formerly exposed in the steep slopes of the park just opposite, and it is penetrated by the railroad tunnel under Byrd Street between Third and Fourth streets.

The formation was penetrated by the well at the Hotel Jefferson, of which the following record is given:

Record of well at Hotel Jefferson, Richmond, Va.

	Feet.
Soil and gravel (Lafayette)	0– 43
Yellow clay	43– 45
Black clay	45– 75
Sand	75– 90
Sand with shells and a little water	90–102
Blue clay	102–118
Soft granite	118–123
Hard and soft granite with water at 410 and 438 feet	123–445

The Calvert and overlying Lafayette formations are 98 feet thick at the brewery on the corner of Harrison and Clay streets, where a well reached the granite at that depth.

The cuts of the Ashland Railroad just northwest of Brook Hill expose 50 to 60 feet of the Calvert formation, part of which consists of fine buff sand in layers. A mile farther north, on the north side of Brook Run, material of this kind extends down to the granite, although there is slight possibility that some of it may be Aquia.

The Calvert formation is exposed at intervals along the slopes of the highlands on the south side of the Chickahominy Valley. One notable exposure of 30 feet of beds is in a gully below the dam of a pond 1¼ miles southeast of Huntslet. Many fossils occur at this place.

Outlier south of Manchester.—The typical gray clay of the formation is exposed for a few rods in a cut of the Belt Line Railroad half a mile west of Clopton. It is the top of a low mound which rises 8 feet above the railroad under a heavy mantle of Lafayette formation. This formation may underlie an area of considerable extent in the ridges southwest of Manchester, but at all other points the Lafayette appears to come down to the granite or to the level of the upper edge of deposits of the Columbia group to the east.

Analyses.—An analysis of material collected by H. Ries[1] from Seventh Street near the locomotive works is as follows:

Analysis of clay of Calvert formation at Richmond, Va.

[Made at Virginia Polytechnic Institute.]

	A	B
Silica (SiO_2)	70.42	63.17
Alumina (Al_2O_3)	15.15	19.30
Iron oxide (Fe_2O_3)	5.17	6.32
Lime (CaO)	.14	.06
Magnesia (MgO)	.79	.69
Potash (K_2O)	2.24	2.45
Soda (Na_2O)	.39	.69
Titanic oxide (TiO_2)	.44	.88
Loss in ignition (H_2O, etc.)	5.21	6.39
	99.95	99.95

The material of sample A was somewhat weathered and contained but few diatoms. Sample B was collected from the same locality but deeper in the bank. The weathered material was much more siliceous and contains a small amount of fine particles and soluble substances due probably to the action of water on the exposed surface.

Another analysis of the diatom deposits from Shockoe Creek valley was made by J. M. Cabel in 1884[2] at the State University. The sample was collected from the middle of the bank just below the colored normal school on President Hill and consists almost entirely of diatoms. It was white with a tinge of yellow, and a mass of it covered with varnish had specific gravity .922. The specific gravity of the powder was 2.321.

[1] Preliminary report on clays of Virginia: Bull. Virginia Geol. Survey No. 2, 1906, p. 143.

[2] University of Virginia University Notes, 116; The Virginias, vol. 6, 1885, p. 3.

Analysis of diatom deposit at Richmond, Va.

Silica (SiO_2)		75.68
Alumina (Al_2O_3)		9.88
Iron oxide (Fe_2O_3)		2.92
Lime (CaO)		.29
Magnesia (MgO)		.69
Potash (K_2O)		.02
Soda (Na_2O)		.08
Nitrogenous matter (Nx6)		.84
Water (by H_2SO_4)	3.37	
Water at 100° C	1.17	
(Less N) by ignition	3.83	
		8.37
		98.77

On boiling in 20 per cent solution of sodium hydrate it was found that somewhat more than one-third of the silica was dissolved; a small additional amount dissolved in another hour and over 50 per cent remained insoluble.

LAFAYETTE FORMATION.

General relations and character.—The plateau surface lying between the larger valleys of the Coastal Plain is covered by a thin sheet of Lafayette formation which also extends westward into portions of the Piedmont province. It consists of sand, gravel, and loam, mostly of pale orange tint, about 30 feet thick. Its surface is remarkably smooth and it mantles unconformably an equally remarkably smooth eroded surface of the older formations. In the Richmond region it lies on the Calvert formation to the east and overlaps on to the granites to the west. It slopes to the east at a rate of about 5 feet to the mile in the eastern part and 20 feet or more to the mile in the granite region. It also slopes down into the larger drainage basins, which evidently were outlined before the deposition of the formation. This local downward slope is well exhibited in the ridge next south of Gillis Creek east of Rocketts and in slopes west of Clopton and along James River above Richmond and Manchester.

The Lafayette formation has been removed along the valleys of James and Chickahominy rivers and their affluents. The smaller branches of the lesser creeks, however, head in the formation and there are wide areas on the divides where the plateau is not incised by drainage and the run-off is sluggish or imperfect and there is considerable seepage underground.

Exposures.—There are some excellent exposures of Lafayette deposits in gravel pits in the north slope of the valley of Bacons Quarter Branch, one-fourth mile beyond the city boundary (Lombardy Street). The cuts show 10 feet of the formation. The upper 3 feet is red loam, which grades down into gravel and coarse buff sands, partly arkosic. Pebbles nearly an inch in diameter predominate, 5

per cent being 2 inches and a few as much as 4 inches. All the pebbles lie flat and the deposit has an obscure bedding. Some are white, others more or less deeply stained orange. Quartzite predominates, but some pebbles and bowlders are quartz and a very few are granites and other crystalline rocks. The red loam at the top thickens to the north and shows pebbly streaks. At one place it is underlain by a layer of gray clay 20 inches thick, pebbly at the base but giving place abruptly to the gravel bed below. In part of this exposure the gravel bed is banded in lighter and darker buff-brown and pinkish tints of varying thickness and continuity. Here the base of the formation is coarse brown conglomerate lying on an irregular surface of the Calvert formation. It appears in the creek just east of Lombard Street and again at a point halfway between that street and Hermitage Road crossing. Fine exposures of the Lafayette are presented just south of the point where Hermitage Road crosses Bacons Quarter Branch.

There are numerous deep cuts in the Lafayette formation in the plateau on the east side of Shockoe Valley, notably at Marshall Street and Twentieth and Twenty-first streets, where the lower member, 8 to 15 feet thick of sand and gravelly sands, grades up into an upper member of orange loam. In the shafts descending to the old Church Hill tunnel the formation was 30 feet thick according to Coryell[1] (see fig. 1, p. 24), and in the well at Hotel Jefferson it was 43 feet to the base of the gravel, lying on yellow clay of the Calvert formation.

The long cuts of the Chesapeake & Ohio Railway through the divide northeast of Highland Park present extensive exposures of the Lafayette formation. The principal material is an orange loam, some portions having a buff tint. It is mostly fine grained, but the lower beds contain much gravel. The cuts of the Ashland Railroad near Brook Hill are in Lafayette formation for some distance. The material is orange loam, gravelly at the base. There are deep cuts in the formation along the Belt Line Railroad on both sides of James River. The deepest cuts begin near Clopton and extend west for more than a mile. In places they are 30 feet deep. The material is the common sandy loam of orange tint, but there are many irregular streaks of gravel and some clay. There is much crossbedding of the coarser materials and local unconformities. The changes in character of sediments are numerous and abrupt. That the orange tint is deepened by weathering is plainly shown in one cut through a rounded knoll, where the deeper orange tint extends to a depth of about 6 feet and curves closely parallel to the surface. There are very instructive cuts along the Belt Line Railroad a short distance north of the bridge

[1] Coryell, Martin, Diatomaceous sands of Richmond, Va.: Proc. Am. Inst. Min. Eng., vol. 4, p. 230; The Virginias, vol. 2, 1881, pp. 6-7.

over James River. There the Lafayette lies on the crystalline rocks with many irregularities of contact and variations in composition. The upper part is a bright orange sandy loam; lower down are streaks and lenses of gravel exhibiting much cross-bedding. Half a mile northeast is the yard of the West End Brick Co., where there is an extensive exposure of the orange sandy loam which caps the plateau on which Richmond is built. At the top is 6 feet of bright orange red loam. It grades down into mottled buff and red loam. A view of this exposure is given in Plate X, *B*.

The Lafayette formation mantling the plateau west of Manchester presents its common characteristics of orange sand or loam with more or less gravel intermixed. The top member is an orange-tinted sandy loam from 3 to 6 feet thick. The most extensive exposures are those above mentioned along the Belt Line Railroad. There are cuts also on Semmes Avenue near Twenty-fourth and Twenty-fifth streets, exposing 6 feet of bowldery orange loam with pebbly streaks lying on decomposed granite. Some of the bowlders are a foot in diameter.

COLUMBIA GROUP UNDIFFERENTIATED.

The terraces in the lower part of Richmond and along James River southward are occupied by loams, sands, and gravels of the Columbia group, which also floors the valley of Chickahominy River and extends up the valleys of Shockoe, Gillis, and Almond creeks. The thickness of most of the deposits ranges from 20 to 30 feet and the altitude ranges from sea level to slightly over 100 feet.

There are remains of two terraces of the Columbia group in the south central part of Richmond. The higher one, with an altitude of about 85 feet, constitutes a very distinct bench occupied by the old canal basin and Byrd Street depot. It may extend to the corner of Main and Twelfth streets and on Canal Street it extends almost or quite to the corner of Seventh Street. The deposits are well exposed on Seventh Street between Byrd and Brace streets and on Tenth Street above and below Byrd Street. Deposits of the Columbia group at a lower level are exposed in the east end of the inclosed yard of the Tredegar Iron Works, at the foot of Seventh Street. The altitude here is about 50 feet, and 8 feet of gravelly sand are exposed, in part stratified. Considerable sand lying on granite on the east end of Mayo Island is probably post-Columbian.

A wide area of deposits of the Columbia group extends along the east side of Shockoe Creek valley and thence along the river bank to Thirtieth Street. Main Street traverses them from the creek crossing nearly to Twenty-seventh Street. They constitute a sloping plain which rises to an altitude of 77 feet at the corner of Main and Twenty-sixth streets and terminates in a low bluff with an altitude of 28 to 40

feet just south of Carey Street from Nineteenth to Thirtieth Street. This bluff exposes buff sandy loam with pebbly streaks lying on the Patuxent formation and near Twenty-fifth Street on the Aquia formation. In the deep cut of the Chesapeake & Ohio Railway at Rocketts Street the Columbia lying on the Patuxent is a buff loam with sandy layers and pebbly streaks, its top being about 44 feet above sea level. A narrow strip of the terrace extends along the south side of Williamsburg Avenue in the vicinity of Thirty-first and Thirty-second streets, rising nearly to an altitude of 50 feet. Near the bank of Shockoe Creek at Turpin and Thirteenth streets is a small mass of deposits of the Columbia group. It has been dug for gravel and consists of sand and gravel irregularly intermixed or interbedded.

Columbia deposits are well exposed, capping the 40-foot bluff which extends along the river bank from Rocketts nearly to Almond Creek. At the top are 3 to 4 feet of brown loam, which thickens to the east and is extensively worked for brick clay on the flat terrace extending to the base of the hills. Next below is a gray loam containing scattered pebbles and lying on brown sand which rests on the Patuxent formation.

There are long exposures in the railroad cuts in the southern part of Rockets, where the Columbia group lies on the arkosic sands of the Patuxent formation. The lower beds contain a large number of bowlders, some of them 3 to 4 feet in diameter, derived from many kinds of rocks, including granites, gneiss, quartzite, and other crystalline rocks, and sandstone. This member grades upward into sand and sandy loam 10 to 20 feet thick.

There are three terraces of the Columbia group on the west side of James River east and southeast of Manchester. The first is the freshet plain, the second is about 20 feet higher, and the third is 30 feet still higher. The first two are flat, but the surface of the highest one is rolling. Granite appears in the steeper slopes and juts up at intervals in the terraces.

In the railroad cuts near the intersection of Semmes and Cowarden streets the Columbia group capping decomposed granite is well exposed. It is 8 to 10 feet thick and consists of gray gravelly loam. At Seventh and McDonough streets there is a 20-foot cut in fine brown loam containing very few small streaks of gravel; this loam was at one time worked for brick clay. At McDonough and Fifth streets the railroad cut exposes granite capped by brown loam with many bowlders and pebbles.

The Columbia deposit near Goode Creek lies on granite. It is a loam with pebbly streaks and has many bowlders in the basal portion. It extends west at an altitude of 110 to 115 feet to the Atlantic Coast Line Railroad where there is a rapid rise to the Lafayette plain.

A fragment of a Columbia terrace extends up the small branch of Gillis Creek, which empties a few rods west of the point where the National Cemetery Road crosses that creek. The beds constitute a small, narrow flat and end upstream with sharp boundaries on adjoining slopes at about 80 feet above sea level. The Columbia group extends up Gillis Creek valley in a terrace nearly one-quarter of a mile wide, but the deposits are cut through nearly as far as the Charles City Road crossing, where there is a wide flat. The Columbia group extends some distance up Stony Run valley, where two faint terrace levels are presented.

ECONOMIC GEOLOGY.

GRANITE.

GENERAL CHARACTER.

The massive granite which comes to the surface over a large area in the western part of Richmond is in greater part well suited for building stone of the highest grade and the supply is inexhaustible. It has been quarried extensively for many years and furnished most satisfactory material for a large number of buildings in Richmond and elsewhere. One of the most notable structures built partly of it is the State, War, and Navy Department building in Washington, the rock for which came from the Westham quarries. The granite is of bluish-gray to light-gray color, remarkably uniform in composition and texture, and free from minerals which cause staining or decomposition. Like most granites it darkens somewhat on long exposure to the weather. The rock is so massive that blocks of the largest sizes can be worked, and large bodies of it are so free from irregularities in texture or color that dimension stone which will match perfectly may be obtained in any quantity desired. There are two principal varieties—one a light-gray rock of moderately coarse grain, which is used for building, and the other a finer-grained, darker, bluish-gray rock, which is selected for monumental work. Nearly all of the granite is jointed in such a manner that it can be worked with great convenience and the presence of heavy flat jointing or "sheeting" is especially advantageous. Ordinarily the joints are so widely spaced that they cause but little waste in quarrying. The surface of the granite is decomposed to a moderate extent in most parts of the area, but the depth to solid rock is seldom greater than 5 feet. In some localities the unweathered granite is found at the surface. The amount of cover or "overburden" varies greatly with the locality. On the high plateau surfaces the covering of Lafayette formation may be 30 feet thick, but on the slopes of the larger depressions the granite comes almost or quite to the surface, and but little stripping is necessary. In places the granite is cut by

narrow dikes of pegmatite and some portions contain knots of darker or lighter rock, but these materials affect little of the stone.

QUARRIES SOUTH OF JAMES RIVER.

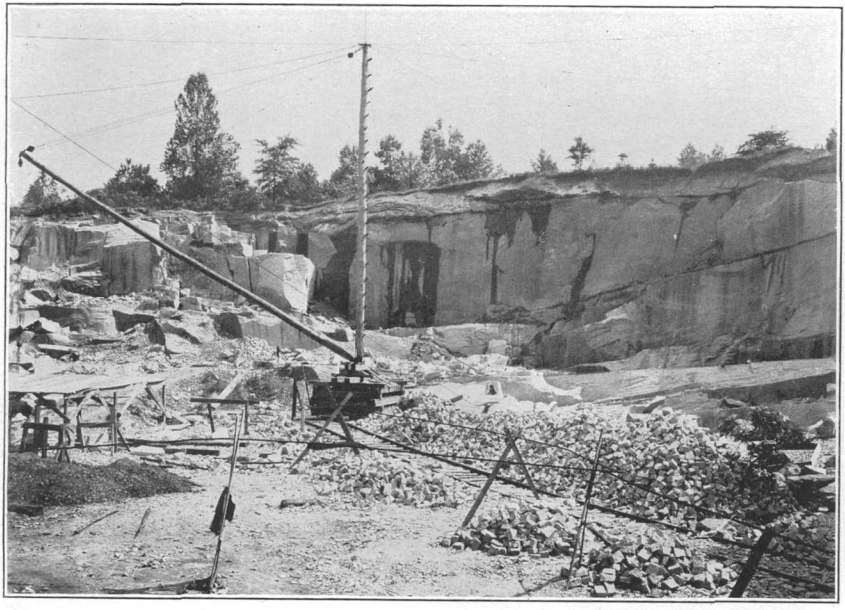
There are 23 large quarries in the vicinity of Richmond, but some of them are not in operation and most of those that have been abandoned are full of water. Some details regarding quarries have been published by Watson.[1] Views of several representative workings are shown in Plates VI to VIII, which illustrate the conditions of quarrying, the nature of the jointing, and other features of the industry.

Granite station on the Richmond & Danville branch of the Southern Railway, about 4 miles west of Richmond, is an important center of the granite industry. A few rods north of the station is a large quarry now worked by Alvin Netherwood for building stone, paving blocks, and crushed stone. About an acre of the granite has been stripped and excavated to a depth of 30 feet. The present working faces are 250 feet long on one side of the quarry and 125 feet long on the other. A large amount of dimension stone is being produced for shipment to various places. The rock is jointed into very thick, nearly horizontal sheets, and there is also vertical jointing at various intervals, which features facilitate the excavation of large blocks. Most of the granite is of light-gray color, moderately coarse texture, and uniform tint, so far as can be judged by the fresh material. A few rods north is the old State quarry, not now in operation. There are two deep openings, one of them 600 feet long and 200 feet wide. It is stated that material for the present Richmond post office was obtained at this quarry. The granite, which is of medium tint and texture, presents the usual heavy horizontal jointing as well as vertical joints and is cut by a few small pegmatite dikes. Watson found a mass of banded gneiss in the lower side of the larger opening, but its relations are not exposed.

A short distance southwest of Granite station are several large quarries, among them the Mackintosh and the Middendorf. The former is probably the largest quarry now being worked in the State. The working area is about 2 acres and a portion has been excavated to a depth of 40 feet. There is a nearly horizontal jointing, which gives the rock a bedded structure favorable for quarrying and also numerous nearly vertical joints trending about N. 10° W. and N. 65° E. In places considerable stripping is necessary. The quarry is equipped with machinery for large output of dimension stone and the material is of most satisfactory quality and appearance. Most of it is of moderately light color and grain, but there is also

[1] Watson, T. L., Granites of the southeastern Atlantic States: Bull. U. S. Geol. Survey. No. 426, 1910.

A. BELLE ISLAND GRANITE QUARRY, FACE AND CRUSHER, FROM NORTH BANK OF JAMES RIVER, IN UPPER RICHMOND, VA.



B. SMITH GRANITE QUARRY, ON SOUTH BANK OF JAMES RIVER, 2 MILES ABOVE RICHMOND, VA.

some of the finer-grained, darker rock. The product of this quarry was used extensively in the State capitol at Richmond.

The Smith quarry, formerly well known as the Netherwood, is an extensive opening on the high south bank of James River, about 2½ miles west of Richmond. It is said to have been in operation for over 65 years. The quarry is about 200 feet long, 200 feet wide, with a working face about 40 feet high. Part of this face is shown in Plate VI, *B*. Two varieties of rock are found—one fine grained and of bluish appearance, used for monumental work, and the other light gray and coarser grained, worked for building stone, paving blocks, crushed stone, etc. As in most of the quarries, there is a nearly horizontal system of joints, dividing the granite into sheets from 2 to 20 feet thick, and a vertical system, trending northeast and northwest, cutting these sheets into huge blocks. Dimension stone of any desired size and of remarkable uniformity in color and texture can be obtained. The fine-grained stone is in a thick vertical mass, which cuts the coarse grained variety, but merges into it in a short distance. Another mass of fine-grained granite in the western part of the quarry is separated by a vertical fault along which the rock is considerably shattered for a few feet on either side. Small streaks of the rock are too coarse grained or pegmatitic for use in building, but this material is utilized for paving blocks or crushed.

Half a mile above the Smith quarry there is a smaller opening known as the Wray quarry, which yields dimension stone and paving blocks of moderately coarse-grained granite of exceptionally good quality. It is on the south bank of the river and slightly above the level of the railroad tracks. The flat jointing is well developed here and the thick sheets of granite dip gently to the southeast. There is widely spaced jointing trending east and west and north and south. The quarry face is about 40 feet long and 30 feet high.

The next quarry on the south bank of the river comprises a series of large openings made by the James River Granite Corporation. It is on the south side of the Southern Railway, half a mile below the crossing of the Belt Line Railroad. The working face is about 110 feet long and 40 to 50 feet high. At the top is about 12 feet of gravel belonging to the Lafayette formation, which has to be stripped. The horizontal jointing is not so well developed here as in some of the other quarries. There are strong vertical joints, mostly trending northeast and southwest. The material is of fine uniform texture and mostly of dark blue-gray color. The rock is cut by numerous dikes of pegmatite and there is a dike of light-colored granite cutting the dark-gray rock in the west end of the quarry. Formerly some excellent dimension stone was quarried here, but now the product is crushed rock for road material and concrete work. This material sells for about $1 a ton, free on board at Richmond.

There are high banks of excellent coarse-grained gray granite extending continuously along the south side of James River below Smith quarry to Manchester, but the rock is not quarried. There is, however, a small old quarry at the south end of the bridge to Belle Island. It has a 30-foot face showing massive coarse-grained granite with considerable variation in color from place to place. The flat jointing is well marked, the joints having low inclination to the southeast, and there are wide-spaced vertical joints.

The ledges on Belle Island have been extensively quarried by the Old Dominion Iron & Nail Works mainly to furnish crushed rock for road material and concrete. The quarry face, 60 feet high, and the crusher are shown in Plate VI, *A*. The horizontal sheeting of the granite is well marked. On the granite there is a cap of gravel and loam belonging to the Columbia group, 5 to 15 feet thick, which has to be stripped. There are two varieties of the rock, one light colored and coarse grained and the other darker colored and finer grained; also scattered pegmatite dikes.

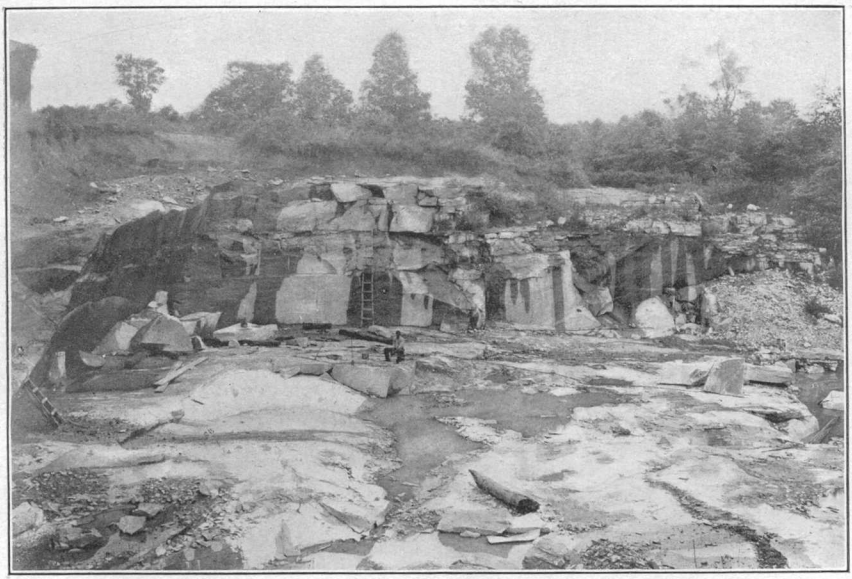
There are two granite quarries south of Manchester—one, now abandoned, on the west bank of James River just below the mouth of Goode Creek, and the other, known as the McGowan quarry, on Broad Branch Run a few hundred yards east of the Petersburg Pike. The McGowan quarry is an extensive producer of granite of exceptionally fine quality used mainly for monuments. The principal working face in the quarry is shown in Plate VII, *A*. The overburden of Columbia deposits and decomposed rock which has to be stripped is about 5 feet thick. The opening is about 125 feet square and 20 to 40 feet deep. The nearly flat jointing is well developed, and the vertical joints are so widely spaced that very large blocks are obtainable. The color and texture of most of the granite are remarkably uniform, and the quarry is capable of producing a large amount of dimension stone.

The old quarry on the west bank of James River at the mouth of Goode Creek has been worked largely for riprap and crushed rock. The excavation is about 100 feet long and 30 to 40 feet deep and considerable stripping is necessary. Some of the rock is much broken and cut by pegmatite dikes, but other portions would afford good dimension stone of medium color and moderately fine even grain.

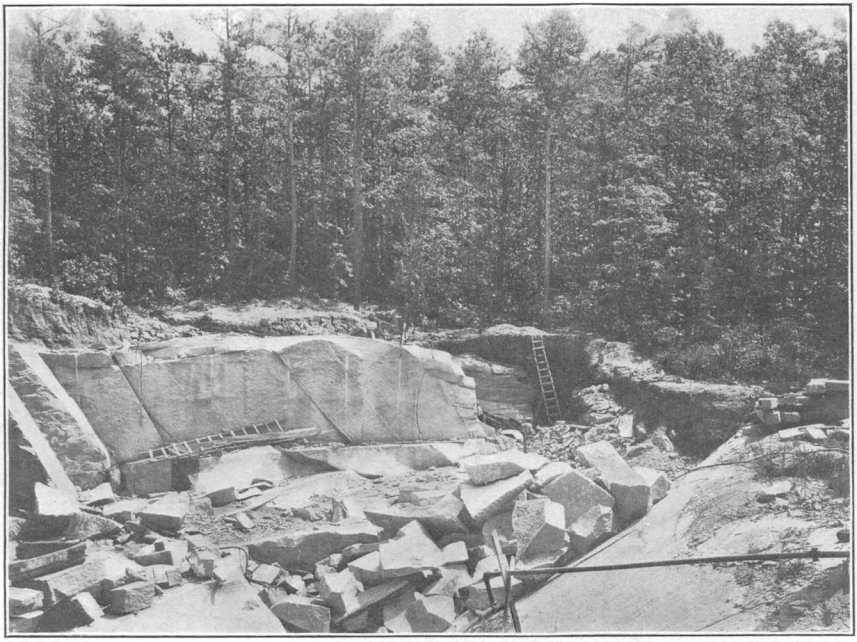
The old Westham and Green quarries, on the south bank of James River a mile northwest of Granite station, are not now in operation. They were extensively worked in years past and show very large working faces of high-grade rock in very thick beds.

QUARRIES NORTH OF JAMES RIVER.

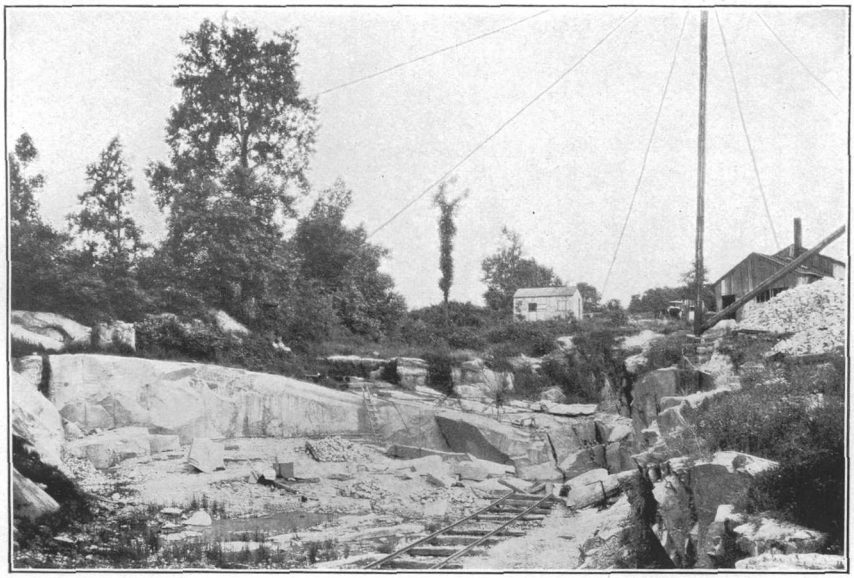
The largest quarries north of Richmond are those of the Richmond Granite Co., on Brook Run a short distance northeast of Morrison



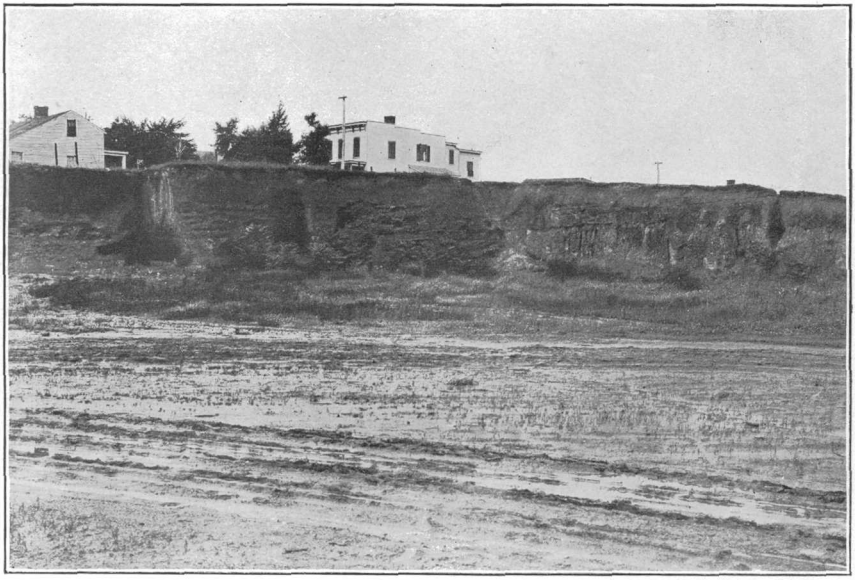
A. McGOWAN GRANITE QUARRY, ON BROAD ROCK BRANCH, NEAR PETERSBURG PIKE, 3 MILES SOUTH OF MANCHESTER, VA.



B. ONE OF THE QUARRIES OF THE RICHMOND GRANITE CO. JUST EAST OF THE RICHMOND, FREDERICKSBURG & POTOMAC RAILROAD, 4 MILES NORTHWEST OF RICHMOND, VA. SHOWS DIAGONAL JOINTING.



A. GRANITE QUARRY OF J. A. McCLOY, ON GROVE AVENUE, IN WESTERN PART OF RICHMOND, VA.



B. UPPER CLAY AT DAVIS BRICKYARDS, ON MAURY STREET, MANCHESTER, VA.

station on the Richmond, Fredericksburg & Potomac Railroad. One of the principal openings is shown in Plate VII, *B*, which is near the eastern end of the property. The workings extend for 600 feet along the hill slope, and portions of them are 40 feet deep, so that the amount of granite in sight is very great. There is heavy horizontal "bedding" in part of the area and well-pronounced diagonal joints, trending northeast and northwest, some of which are shown in Plate VII, *B*. Most of the rock is very massive and of uniform texture and color, yielding very high-grade dimension stone of any size desired. There are local developments of irregularly coarse-grained rock, but it does not interfere with the quarrying. A small amount of gravel and sand has to be stripped and some of the surface rock is too much decomposed to be used. Considerable granite from this quarry is cut into paving blocks, and the waste is crushed for concrete and road metal.

The McCloy quarry is on the western margin of the city of Richmond about 500 yards west of the new reservoir. The working face is about 100 feet long and 20 feet high, and there is a thin capping of sand and gravel of the Lafayette formation which has to be stripped. A portion of the workings is shown in Plate VIII, *A*. The rock is fine-grained bluish-gray and generally of uniform composition, texture, and color. The horizontal jointing, so general in the Richmond region, is well developed and there are also wide-spaced upright joints trending in various directions and sloping to different degrees. A moderate amount of dimension and monumental stone of superior quality is now produced, together with paving blocks and crushed stone. The quarry could be opened much more extensively and a large quantity of high-grade material could be obtained easily.

The Winston quarry is on the north bank of James River near the James River branch of the Chesapeake & Ohio Railway, about 4 miles west of Richmond. It is in a bluff with a working face about 100 feet high opened over an area of about 1 acre. The common horizontal jointing is a prominent feature together with steep dipping joints, which trend N. 5° W. and N. 30°–70° E. The granite is sheeted with sheets thickest at the bottom and thinnest at the top. This quarry is capable of furnishing dimension stone in large amount, but has been worked mainly to supply crushed stone and rough blocks. Several other quarries have been worked along the same bluff above and below the Winston openings and all present the same features.

SHIPPING.

There are excellent facilities for shipping in most parts of the Richmond granite area, for it is traversed by several railroads. The only quarry on tidewater is the abandoned one on the west bank

of the James River at the mouth of Goode Creek, but it is only a short haul from other quarries to barges and other means of water transportation to all parts of the east coast of the United States. Above the old Manchester bridge the James River is not navigable, but the canal follows the foot of the granite bluffs on the north side of the stream. The quarries near Granite and on the south bank of James River have their outlet by the Southern Railway; the McGowan quarry is on a spur of the Seaboard Air Line Railway, and the Richmond Granite Co.'s quarries are on a spur of the Richmond, Fredericksburg & Potomac Railroad. The expense of getting the stone to market is relatively small as compared with the cost of preparing it in the quarry and shop. As the demand for stone increases, new quarries could be opened at many points along both banks of James River and also in the Brook Run and other smaller valleys which traverse the granite area. These could easily be reached by spurs from the various railroads.

Nearly all of the granite is workable, although some portions of it are of better quality than others, and the items of stripping, drainage, and jointing are factors of greater or less importance. The principal need is to create an increased demand by securing contracts which now go to other granite markets. A necessary condition also is to manage the quarry so as to fulfill contracts rapidly and with stone of satisfactory character as to color and finish.

BRICK CLAY.

There are extensive deposits of loamy clays constituting portions of the Columbia group and the Lafayette formation in the Richmond region, and the clays of the Calvert formation may prove to be suitable for brick making. There are many brickyards utilizing the clays of the Columbia group and in two places the loams of the Lafayette are used. Most of the brick produced are not of especially high grade. They are used locally and scarcely supply the present active demand. Some of the yards use primitive methods of treatment and burning, and with more modern methods the product could be materially improved. The largest plant is that of the Fuller Brick Co., on the Chesapeake & Ohio Railway 4 miles southeast of the city, where high-class methods are employed.

The clay used in the Richmond region is more or less mottled, gritty, yellow or reddish, some of it sandy and much of it contains streaks of pebbles and large bowlders, which differ in amount in adjoining yards. The clay differs in quality, even in the space of a single working face, and a combination of the varieties has been found to produce the best results. The depth of the clay varies from 6 to 18 feet, and in most areas the clay is underlain by a bed of sand.

A detailed investigation of the brick clay of Virginia has been made by Heinrich Ries [1] for the Geological Survey of Virginia, and most of the following data are taken from his report.

COLUMBIA GROUP.

Manchester.—Four yards are in operation in Manchester, just across the river from Richmond. They are all in the vicinity of Knight and Maury streets. These yards manufacture soft-mud brick, but they also produce a small amount of pressed brick. The clay used is more or less mottled, gritty, yellow or reddish, and is covered by a thin layer of sandy soil and commonly underlain by a bed of sand. In the yard of Green & Harrison the underlying granite is reached. The clays in general are very tough and plastic, but portions are sandy, and some contain a variable quantity of stony material which ranges in size from small pebbles to large bowlders, most of these being of crystalline character. This stony material is not uniformly distributed through all the clay, but lies in streaks, the greatest quantity occurring in the yards of W. J. Ready and Green & Harrison.

The yards of W. J. Ready, G. E. Redford, and W. B. Davis adjoin. Ready's has the deepest pit, and it also lies at a slightly lower level, for the upper surface of the clay is uneven and slopes toward the river. The thickness of the clay is said to be 18 feet and over. The clay is somewhat similar to that found in the neighboring yards, but it varies rather markedly in character, containing more stones and bowlders. Three different kinds are recognized in a working face about 200 feet long; of these only one, that from the northwest corner of the bank, can be used alone with good results. The clay from the west side of the bank is too tough and would crack on drying or burning, so it is tempered by admixture with the very sandy clay in the southeast corner of the bank. Analyses and tests of these clays are given below.

In Redford's yard the clay is from 12 to 17 feet thick, but the working face has a height of only 6 to 8 feet. It is a mottled gritty clay with mica fragments and many limonite stains scattered through it, and it contains also many decomposed pebbles of crystalline rock. The material is red burning. The pit is a large shallow excavation, and the run of the bank is used, for the clay, like that in Ready's yard, varies in physical character and unless mixed yields imperfect products. The bricks are molded by hand, dried in open yards, and burned in updraft kilns with permanent side walls. The fuel is wood or coal.

Davis's yard, on Fourteenth Street just south of Maury, contains a large shallow pit, with a working face 8 to 12 feet high. (See Pls.

[1] Preliminary report on a part of the clays of Virginia: Bull. Virginia Geol. Survey, No. 2.

VIII, *B*, and IX, *A*.) The clay is like that used in Redford's yard, but contains fewer stones. From the evidence of a 16-foot well in the yard it is believed that the clay is 20 to 25 feet thick and underlain by whitish sand. The brick, which are of the soft-mud variety, are made in a Hercules machine, dried in open yards, and burned in updraft kilns with permanent side walls. The fuel is wood and coal. The capacity is about 50,000 a day.

The Green & Harrison yard is just east of Ready's. It has a small pit, and a portion of the clay contains many bowlders. In its northwest corner the granite has been reached.

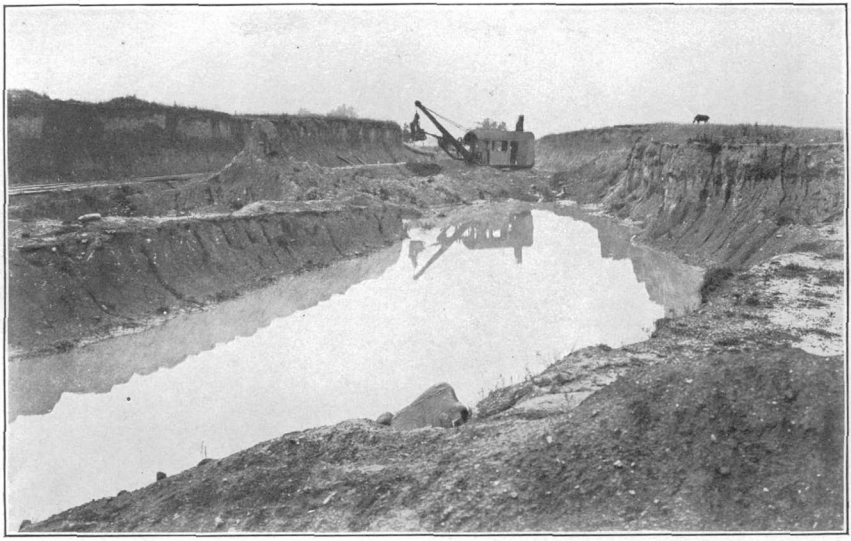
Rocketts.—The Fulton Brick Co. operates a yard for common brick west of the Chesapeake & Ohio Railway roundhouse. It is commonly spoken of as the Westford yard. The clay is removed to a depth of about 10 feet. Portions of it contain many cobblestones. It is underlain by a fine sand, at least 8 feet thick, which is used for sanding the brick molds. The clay is tempered in ring pits, molded by hand, and burned in Dutch kilns.

Two yards are operated by the Baltimore Brick Co. at Rocketts, near the intersection of Ohio and Williamsburg avenues. The clay is tempered in ring pits, molded by hand, and burned in Dutch kilns. It is dug from pits in the vicinity of the yard and averages from 15 to 18 feet in thickness, being underlain by sand. The clay is similar to that in the yards at Manchester, but lacks the stones and bowlders. In the southern yard the clay is molded by hand and burned in Dutch kilns. The product has a good ring, but is not very smooth or bright in color.

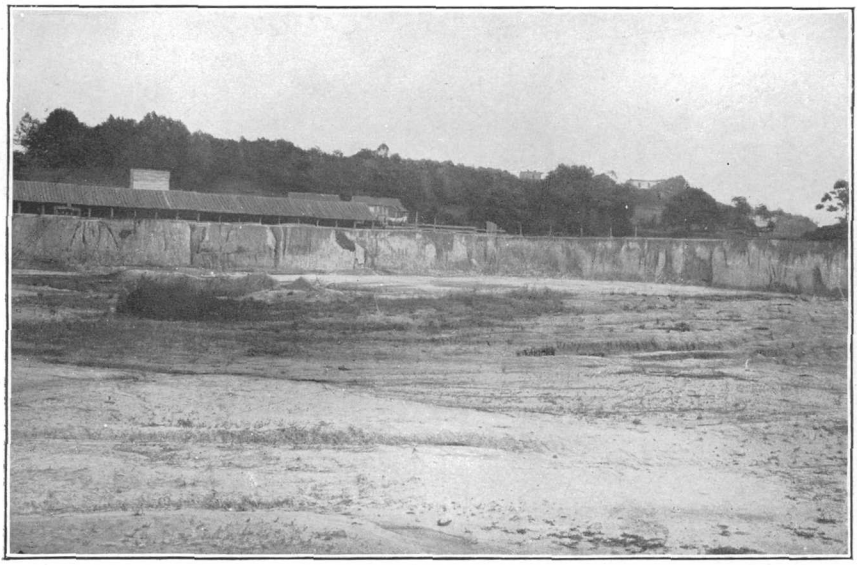
Southeast of this yard is one operated by Maynard & Powers. It is stated that the clay runs 20 feet in depth and is underlain by a bluish-gray sand. The working face is about 12 feet high and shows a sandy, mottled, yellowish-brown, and gritty clay similar to that occuring in the other pits in the vicinity. A sample (No. 1300) representing run of the bank was analyzed and tested, with results given below. The clay is tempered in ring pits, molded by hand, dried in open yards, and burned in Dutch kilns. A dry-pressed bricklet burned to cone 1 had a fire shrinkage of 4 per cent and burned to a light-red color. The clay is classed as a common brick clay which burned steel-hard and had an excellent color at cone 05. It gives a rather rich red at cone 1, but at cone 3 the color is too deep to be attractive.

LAFAYETTE FORMATION.

Fort Lee.—A group of yards is located at Fort Lee on the Chesapeake & Ohio Railway, about 4½ miles southeast of Richmond. The general run of clays is like those used nearer Richmond, but the stony material is lacking.

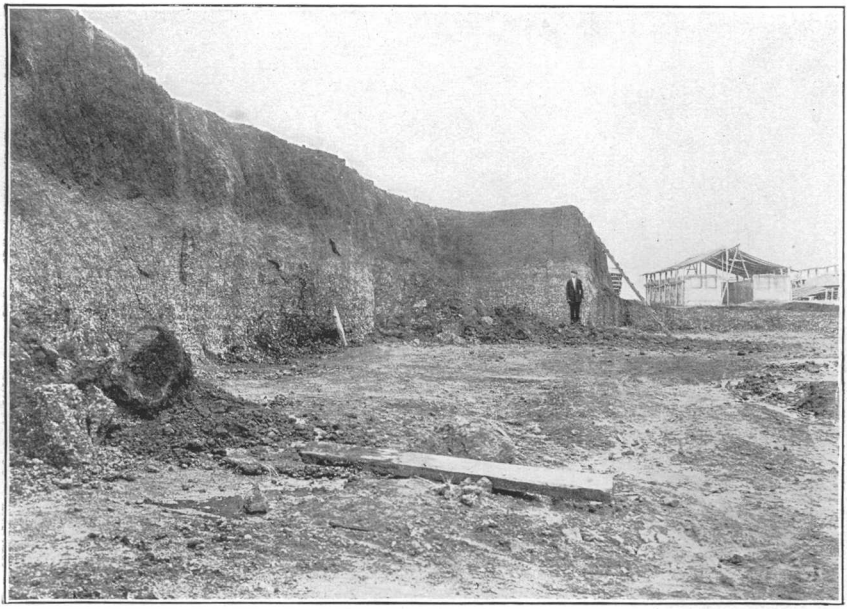


A. MAIN WORKING FACE OF DAVIS BRICKYARDS ON MAURY STREET, MANCHESTER, VA. SHOWING COLUMBIA FORMATION.



B. TYPICAL FACE OF BRICK CLAY AT ROCKETTS, RICHMOND, VA. SHOWING COLUMBIA FORMATION.

A. LAFAYETTE FORMATION IN BRICKYARD OF FULLER CO., NEAR FORT LEE, 5 MILES SOUTHEAST OF RICHMOND, VA.



B. WORKING FACE OF LAFAYETTE FORMATION IN WEST END BRICKYARDS, NEAR CAREY STREET ROAD, RICHMOND, VA.

The C. H. Oliver yard is located 1 mile west of Fort Lee. The clay here lies at the surface and the bank shows 12 feet of it, although the total thickness is said to be 20 feet. A bed of gravel and sand of unknown thickness underlies it. For making bricks the run of the bank is used. The clay is mottled in character, the mottling consisting of yellow and bluish-white clay, the latter being tougher than the former, and unless the material is thoroughly pugged before molding the bluish-white clay shows up in the product in the form of light-colored lumps. Analyses and fire tests of the clay from this bank are given in the table below. The clay may be classed as a common-brick clay, which burns to an excellent light-red color up to cone 03, rich red at cone 1, and vitrifies not far from cone 5. At cone 8 it begins to swell, owing to the fact that portions of it fuse. These fused parts are evidently small specks of iron oxide which are scattered through the clay. Care has to be taken to pug the clay thoroughly or the lumps will cause trouble in drying and burning. The clay is put through rolls and then through a soft-mud machine. The bricks are dried on pallets and burned in Dutch kilns.

Adjoining this yard on the west is that of J. M. Davis where the clay is similar. It is molded by hand, dried in kilns and on pallets, and burned in Dutch kilns. A few hundred feet up the track on the north side are two yards operated by the Fuller Brick Co. (See Pl. X, *A*.) The material is practically the same as that in the Davis yard. Here the clay is loaded on tramcars and hoisted into the plant. It passes first through rolls and then into a Freese side-cut auger machine. The clay does not appear to be difficult to work, but still the lumps of bluish gray clay are not throroughly broken and they show in the finished product. The material flows very smoothly through the die of the machine. It next passes to drying tunnels which are steam heated and remains from 38 to 40 hours. The burning is in Dutch kilns. It is evident from the results obtained that the clay will not stand rapid drying in the steam tunnels, for there are many cracked bricks. In the burning also it was noted that in several of the kilns the two rows coming above the arch were nearly vitrified, while the others were by no means so.

Ries calls attention to the fact that the clays of the Fort Lee area are less stony and less sandy than most of the others now worked about Richmond, and they could be manipulated to advantage by more improved methods. They are somewhat too siliceous for any other use than brickmaking, although probably draintile and hollow brick could be made from them, especially if purer clays are mixed in.

West End.—West of the reservoir in the city of Richmond is the West End yard. It is an extensive excavation in the Lafayette formation, which here consists mainly of loam. In places the loam is 20 feet thick, but portions of it contain considerable sand streaked with gravel. Part of the working face is shown in Plate X, *B*.

CALVERT FORMATION.

The clays of the Calvert formation underlie all of the high ground in the central part of Richmond and to the south, but as yet they have been utilized at only one yard, that of Cheatwood & Blunt. They are largely covered by the Lafayette formation, but at many points they could be excavated at moderate expense. Some of these clays are very pure and run low in silica, but others are more sandy and some consist of alternations of clay and sand which could be mixed together.

At the Cheatwood & Blunt brickyard, east of Brook turnpike north of Bacons Quarter Branch, clay of the Calvert formation is used. It is mixed with 15 to 20 per cent of sand from the upper part of the Lafayette formation. The clay contains fine sand and diatoms and apparently also a large proportion of silicate of alumina. When used pure it shrinks greatly on burning, one test brick 9½ inches long shrinking to 7½ inches. The mixing with sand is done by hand and is not very thorough, but the finished product is a compact brick of good color and great hardness. The capacity of the yard is about 28,000 a day.

Ries examined an outcrop of the clay belonging to the Calvert formation on the Williamsburg Road leading to Stagg's mill about half a mile west of the point where the road crosses the railroad. It is exposed on a sloping hillside and in such position that a large quantity can be removed without having to strip off much overburden. It is also well located for shipment. As far as can be foretold the bed is not less than 20 feet thick. It is a grayish clay which slacks slowly and works with 27.8 per cent of water to a mass of high plasticity. Its air shrinkage, 12.6 per cent, is somewhat high; as is also its average tensile strength of 300.9 pounds to the square inch. This clay is more plastic, denser burning, and less sandy than any of the clays now being worked in the Richmond area. Tempered with sand it could be utilized for brick making.

ANALYSES AND FIRE TESTS.

Analyses and results of fire tests by Ries of this and other clays are given in the following tables:

Analyses of brick clays from Richmond, Va.

	No. 1324.	No. 1325.	No. 1326.	No. 1300.	No. 1302.	No. 1330.
Silica (SiO_2)	73.38	69.43	72.61	71.50	69.55	63.06
Alumina (Al_2O_3)	13.53	14.79	13.08	13.86	15.79	20.90
Iron oxide (Fe_2O_3)	5.53	6.70	5.61	7.48	6.05	6.29
Lime (CaO)	.58	.57	.96	.56	Trace.	.16
Magnesia (MgO)	.14	.63	.23	.11	.08	.45
Potash (K_2O)	2.32	2.26	2.45	2.29	1.54	3.13
Soda (Na O)	.47	.71	.44	.81	.38	.68
Titanic oxide (TiO_2)			.44	1.44	1.06	.04
Loss on ignition	4.03	4.85	3.65	4.61	5.52	5.29
Total	99.98	99.94	99.96	99.96	99.97	99.97
Total fluxes	9.04	10.87	10.18	8.55	8.05	10.68

Nos. 1324 to 1326 are from W. J. Ready's pit in Manchester. The first can be used alone, but the other two have to be mixed. No. 1324 is from the northwest corner of the bank. It burns to a good red color up to cone 03, but above that it becomes unsightly and at cone 5 it is very close to melting. No. 1325 is from the west side of the bank and is too tough to be used alone. When wet it is very plastic, but also gritty. It does not burn to a very dense body and has a comparatively low fire shrinkage. It becomes steel-hard at cone 1 and at cone 8 is very close to melting. No. 1326, from the southwest corner of the bank, is very sandy and has a low fire shrinkage.

No. 1300 is from Maynard & Power's pit in Rocketts.

No. 1302 is from the yard of C. H. Oliver, 1 mile west of Fort Lee. A dry-pressed bricklet burned at cone 1 showed a light-red color and a shrinkage of 4 per cent.

No. 1330 is on the Williamsburg Road leading to Stagg's mill about one-half mile west of the point where the road crosses the railroad. It becomes steel hard at cone 05. It has a light-red color up to cone 03, but at cone 1 gives an excellent dark-red color. Vitrification is reached at about cone 3 and at cone 5 it was well past vitrification, having swelled considerably.

Fire tests of brick clays from Richmond, Va., region.

WET MOLDED BRICKLETS.

	No. 1324.	No. 1325.	No. 1326.
Color	Yellow buff	Brown	Brown buff.
Water required	20.3 per cent.	20.3 per cent.	18.7 per cent.
Slaking	Moderately fast.	Moderately fast.	Fast.
Plasticity	Good	Good	Fair.
Grit	Sandy	Sandy	Sandy.
Air shrinkage	7 per cent.	6 per cent.	6 per cent.
Average tensile strength	93.7	132	99.
CONE 010.			
Fire shrinkage	Swelled slightly	Swelled slightly	Swelled slightly
Color	Light red.	Light red.	Light red.
Absorption	15.5	17.5	16.4.
CONE 05.			
Fire shrinkage	1.3	2	0.6.
Color	Red.	Light red.	Red.
Absorption	12.9	16.8	15.1.
CONE 03.			
Fire shrinkage	1.6	2.6	1.
Color	Red.	Moderately red.	Red.
Absorption	11.4	12.1	14.4.
CONE 1.			
Fire shrinkage	3.7	3.6	2.
Color	Dark red	Dark red	Red.
Absorption	6.2	9.8	10.3.
CONE 3.			
Fire shrinkage	5.3	4.	3.
Color	Dark red	Dark red	Dark red.
Absorption	3.4	8.7	8.2.
CONE 5.			
Fire shrinkage	5.	5.	5.6.
Color	Dark red.	Dark red.	Red.
Absorption	1.4	6.3	1.6.
CONE 8.			
Fire shrinkage	5.5	Vitrification begins.	6.
Color	Dark red.	Red brown.	Red brown.
Absorption	0.2	1.5	1.

Fire tests of brick clays from Richmond, Va., region—Continued.

	No. 1300.	No. 1302.	No. 1330.
Color	Yellow buff	Yellow buff	Grayish.
Water required	20.9 per cent	24.2 per cent	27.8 per cent.
Slaking	Moderately fast	Moderately fast	Slowly.
Plasticity	Good	Good	Good.
Grit	Fine	Much fine	None.
Air shrinkage	6.4 per cent	8.6 per cent	12.6 per cent.
Average tensile strength	89.6	60.6	301.
CONE 010.			
Fire shrinkage	0	0	1.
Color	Light red	Light red	Pink.
Absorption	17.4	20.2	14.4.
CONE 05.			
Fire shrinkage	1.6	1.6	3.
Color	Light red	Light red	Pink.
Absorption	15.1	17.6	8.9.
CONE 03.			
Fire shrinkage	1.6	4	5.
Color	Light red	Light red	Light red.
Absorption	14.1	14.1	5.7.
CONE 1.			
Fire shrinkage	5	6.3	7.6.
Color	Red	Light red	Red.
Absorption	7.1	7.5	1.1.
CONE 3.			
Fire shrinkage	6.3	7	7.6.
Color	Dark red	Light red	Dark red.
Absorption	4	5.9	0.1.
CONE 5.			
Fire shrinkage	6.6	8.3	2.
Color	Gray brown	Dark red	Gray.
Absorption	1.4	2.6	2.4.
CONE 8.			
Fire shrinkage	6.3	7.3	0.3.
Color	Red brown	Brown	Drab.
Absorption	1.3	1.1	1.6.

Representative samples of brick clays from Rocketts and from West End Yards were collected by the writer and sent to the chemical laboratory of the United States Geological Survey at Pittsburg, Pa., for analyses. In drawing these samples a large amount of material was taken from various parts of the banks and quartered down. The following analyses and tests were made by A. V. Bleininger:

Analyses of brick clays from Richmond, Va.

	A	B
Silica (SiO_2)	73.39	70.91
Alumina (Al_2O_3)	14.07	15.91
Ferric oxide (Fe_2O_3)	4.31	3.15
Titanium oxide (TiO_2)	1.02	1.01
Lime (CaO)	.09	.15
Magnesia (MgO)	.35	.66
Soda (Na_2O)	.16	.47
Potash (K_2O)	.42	1.24
Water at 100° C	1.32	1.85
Ignition loss	4.91	4.75

A. From Lafayette formation in yards of West End Brick Co.
B. From Rocketts Yards.

The material of analysis A is a reddish clay, very high in sand, and is so deficient in plasticity that it can not be worked by the stiff-mud process, but only by hand molding or in the soft-mud machine. Its drying shrinkage, however, is 7.4 per cent in terms of the dry length and the burning shrinkage 2.2 per cent at 1,150° C. The clay stands up well in the fire and is not easily overburnt. It can not, however, be made to produce vitrified products without serious kiln loss. The color is a good clean red.

The other sample (analysis B) is a soft, buff-colored clay, possessing good working plasticity, which would make it suitable for the manufacture of stiff-mud brick, tiles, etc. Its texture is very much finer than that of sample A. It does not check or warp in drying. The drying shrinkage is 6.8 per cent in terms of the dry length. The burning shrinkage is 1.3 per cent at 1,150° C. and 5.8 per cent at 1,250°. The clay has a long vitrification range, and hence is a safe material to burn, resulting in low kiln loss. The color is an excellent clean red.

The material of analysis B is greatly to be preferred to that of analysis A in every respect as far as working quality, drying, and burning behavior are concerned, and in addition the strength of the former when burnt is decidedly greater than that of the latter, which, unless burnt to about 1,150° C., is inferior in this respect and apparently not able to withstand the effects of freezing and thawing for any considerable number of years.

MOLDING SAND.

Portions of the Aquia formation and the Columbia group consist of sand suitable for molding and they are the source of local supply. Certain peculiar features are requisite in molding sand. It must be sufficiently fine grained and coherent to take sharp impressions in the molds, resistant to heat, porous enough to permit escape of steam and gas, and free from materials which will give off gases or cause shrinkage. A small percentage of clay is necessary to make the sand coherent, but if the amount is too great it causes shrinkage, which is a most disadvantageous quality.

The largest pit is in the sand of the Aquia formation on the south side of Almond Creek, one-fourth mile above the crossing of the road that passes through the Rocketts brickyards to join the Charles City Road. The deposit is overlain by the Calvert formation and the face exposed is about 15 feet high. The sand is gray and greenish, mottled with buff blotches. Another smaller pit is on the east side of the road above mentioned, just south of the crossing of Almond Creek.

The sand underlying the brick clay in G. E. Redford's yard in the vicinity of Knight and Maury streets, Manchester, is used to a considerable extent for molding.

A number of molding sands from the Richmond region, collected by H. Ries, were analyzed at the Virginia Polytechnic Institute[1] by J. R. Eoff, jr., and J. H. Gibboney, with the following results:

Analyses of molding sands from Richmond, Va.

	No. 1.	No. 2.	No. 3.	No. 4.
Silica (SiO_2)	81.59	82.08	66.12	82.32
Alumina (Al_2O_3)	6.46	7.12	16.54	7.80
Iron oxide (Fe_2O_3)	4.94	4.63	4.46	3.98
Lime (CaO)	.14	.36	.40	.54
Magnesia (MgO)	.22	.35	.22	.41
Potash (K_2O)	1.19	1.28	2.67	1.64
Soda (Na_2O)	.59	.41	.35	.80
Titanic oxide (TiO_2)	1.90	.30	.14	.22
Water (H_2O)	1.63	1.66	4.90	.19
Water (moisture)	1.46	1.52	4.15	.14
	100.12	99.71	99.95	98.04

No. 1. Sand (Redford pit) from foundry, Manchester, Va.
No. 2. Yellow sand collected at Redford pit, Manchester, Va.
No. 3. Coarse sand, Harbaugh pit, Richmond, Va.
No. 4. Used sand, Redford pit, Manchester, Va.

The following physical tests were made by Ries.

Physical tests of molding sands from Richmond, Va.

Sample.	20 mesh.	40 mesh.	60 mesh.	80 mesh.	100 mesh.	100 mesh.[1]	Clay.
							Per cent.
No. 2	1.51	1.26	1.27	0.56	6.27	71.69	16.52
No. 3	42.48	12.90	6.16	.85	1.70	8.58	26.44
No. 4	5.34	14.73	10.41	1.28	14.61	59.37	3.52

[1] Passed through 100-mesh sieve.

DIATOMACEOUS EARTH.

The diatom deposits forming part of the Calvert formation about Richmond have so far not been utilized. The deposits are irregular in form and the amount of high-grade material available is not as large as at some other localities in Virginia and Maryland. The purer deposits are soft claylike material, which when dry is of very porous texture, of white color or slightly yellowish tint, and exceedingly light weight. It is mostly fine silica and consists of the minute frustules of plants known as diatoms. The chief use for diatomaceous earth is for cleaning and polishing, either in the form of powder or mixed with soap. It is an effective nonconductor of heat and has been used alone or with various compounds for coverings for boilers, steam pipes, and safes, and in fireproof cements. Its great absorbent qualities fit it admirably for use in water filters and for dynamite. For the latter use it is mixed with wood pulp. It is used largely by paint manufacturers as a wood filler. Boiled with shellac

[1] Mineral resources of Virginia, pp. 394–395.

it is made into records for talking machines. In Germany it has been used for absorption of liquid manures so that they could be utilized as fertilizers, as a source of silica in making water glass, in the manufacture of cement, tile glazing, artificial stone, ultramarine and other pigments of aniline and alizarine colors, paper filling, sealing wax, fireworks, hard-rubber objects, matches, papier-mâché, for solidifying bromine, and for many other purposes. In preparing the earth for market it is first roasted in large rooms in order to expel much of the water and organic matter. It is then transferred to a furnace and heated to a moderately high temperature, but with care not to destroy the porosity by overheating. It is then ground fine between rollers, sieved, and promptly sacked to prevent reabsorption of moisture. For some uses it is only necessary to give a prolonged drying in a chamber heated by steam pipes prior to grinding and sieving. The value runs from $6 to $9 a ton. California, Illinois, Maryland, Massachusetts, Missouri, and New York are the principal sources in this country, and about 3,000 tons a year are imported.

Two samples of the diatom deposit in the Calvert formation in Richmond have been tested by Ries as to their suitability for brick or other wares. They were collected from Seventh Street near the locomotive works. One sample (A) was weathered material, the other was from a point deeper in the bank. Analyses are given on page 26, which indicate that in the material of sample A 8.73 per cent of fluxes are contained and 31.6 per cent of water was required. Some grit was found and the air shrinkage was 13. In sample B there are 10.21 per cent of fluxes, 34.6 per cent of water was required, and air shrinkage was 14.

The fire tests give the following results:

Fire tests of diatom deposits from Richmond, Va.

	1,720° F., cone 010.	1,922° F., cone 05.	1,994° F., cone 03.	2,102° F., cone 1.	2,174° F., cone 3.	2,240° F., cone 5.	2,354° F., cone 8.
Sample A:							
Fire shrinkage	0.6	0.6	2.0	3.0	3.3	5.0	2.0
Color	Light red.	Light red.	Light red.	Light brown.	Red brown.	Red gray.	Brown.
Absorption	14.6	13.6	12.4	9.1	6.9	5.0	2.0
Sample B:							
Fire shrinkage	6.0	2.3	3.3	5.0	6.0	6.0	5.5
Color	Light red.	Light red.	Light red.	Medium red.	Medium red.	Red gray.	Red gray.
Absorption	14.9	10.9	9.0	4.2	2.3	1.7	1.1

A sample of much finer material from Maryland, when tested with cone 27 (temperature 3,038° F.), fused into a brownish glass, which demonstrates that it is not refractory at high temperature.

The higher silica content in sample A appears to affect its porosity and shrinkage in burning.

OCHER.

For many years yellow ocher of fine quality was produced near Bermuda Hundred, 15 miles southeast of Richmond. The mine was on the north branch of Appomattox River just below the mouth of Ashton Creek, 4 miles southeast of Bermuda Hundred. The first extensive operations were in 1872, when the material was placed on the market as "Bermuda ocher" at 2½ cents a pound in competition with imported ocher selling at 3¾ cents a pound. Its superior quality was at once recognized, and for many years it found a ready market, although the price dropped to an average of $22 a ton. In 1880 the production was 1,000 tons, produced by 30 workmen. The crude ocher was washed, dried, and ground, and three grades were produced, "single washed," "double washed," and "extra floated." The values were, respectively, $18, $21, and $27 per ton. Production of of this material continued for about 30 years, when apparently the deposit gave out. The place is now abandoned and the workings are caved in.

The ocher is a yellow earthy mineral consisting of sesquioxide of iron in hydrous form mixed with a small amount of clay. In observations made 15 years ago the writer found that it occurred in a bed 3 to 5 feet thick, of which the upper 2 feet or more was the purest. It is a member of the Patuxent formation, and at the mines was overlain by about 30 feet of typical arkosic gravelly sand of that formation capped by gravels of Lafayette formation. Below the ocher is green sandy clay grading into 80 feet of gray sand.

The ocher was exposed for about 800 feet along the slope of the bluff. Its western termination was not visible, but to the east it was seen to thin rapidly and to disappear a few rods east of the pits. Here the green sandy clay and sand thicken to 10 or 14 feet and are underlain by typical arkosic sands filled with pebbles and bowlders extending down to the water. It is believed that the ocher was deposited as a bog iron ore in some pool of restricted area.

This occurrence of ocher in the Patuxent formation is a most exceptional feature, for no deposits of the material have been found in it elsewhere. It is possible, however, that they may occur, and the material should be carefully looked for in new cuts and wells throughout the area of the formation. A deposit similar to the one west of Bermuda Hundred would be of considerable value.

CONCRETE MATERIALS.

An abundant supply of crushed granite and coarse river sand is available for concrete in Richmond. One large quarry, on Belle Island in James River, is worked by the Old Dominion Iron & Nail Works to supply crushed granite, which is sold in Richmond for $1.60

to $1.80 a ton delivered. A sample (No. 9) of this material was sent to the laboratory in Pittsburg to be tested.

Gravel is dug at several pits within the city limits and brings at present from $1 to $1.25 a yard delivered. It is a quartz and quartzite mixture, consisting mainly of very hard material. One pit on Gillis Creek screens gravel from the Patuxent formation. Others in the northern part of the city on Cannon Creek screen the Lafayette formation, which here consists largely of gravel. Nearly all the contractors in Richmond have a strong preference for the crushed granite.

Sand for concrete is pumped from James River through washers and screens. One of the principal producers is Stephen A. Ellison & Co., at Seventeenth and Dock streets. A sample (No. 8) of this sand was sent to the Pittsburg laboratories. The sand is sold for 50 cents a yard on the bank of the river. An examination of this sand made September 23, 1908, by Froehling & Robertson, chemists, of Richmond, showed the following sizes of grains:

	Per cent.
$\frac{1}{4}$ to $\frac{1}{10}$ inch	7.1
$\frac{1}{10}$ to $\frac{1}{20}$ inch	16.5
$\frac{1}{20}$ to $\frac{1}{30}$ inch	15.5
$\frac{1}{30}$ to $\frac{1}{40}$ inch	27.1
$\frac{1}{40}$ to $\frac{1}{50}$ inch	19.4
$\frac{1}{50}$ to $\frac{1}{60}$ inch	3.0
$\frac{1}{60}$ to $\frac{1}{80}$ inch	10.2
$\frac{1}{80}$ to $\frac{1}{100}$ inch	1.0
Finer than $\frac{1}{100}$ inch	.2
	100.00

These proportions are highly advantageous and briquet tests made with high-grade Portland cement showed very high strength. The grains are nearly all quartz, and sharp. The freedom from silt is due to the vigorous washing which the sand receives when it is pumped into the scows.

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